DOCUMENT RESUME

ED 082 951 SE 015 963

TITLE	Articulated Multimedia Physics, MBO List. Measurable Behavioral Objectives, Lessons 1 through 14.
INSTITUTION	New York Inst. of Tech., Old Westbury.
PUB DATE	[65]
NOTE	72p.
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	*Behavioral Objectives; *College Science; *Computer Assisted Instruction; Educational Objectives; Instructional Materials; *Multimedia Instruction; *Physics; Remedial Instruction; Science Education

ABSTRACT

A list of measurable behavioral objectives (MBO) is presented in this booklet for use throughout the Articulated Multimedia Physics Course. The objectives are divided into terminal and enabling objectives. Computer analyses of student's achievement are given in the form of the MBO number. The objectives are grouped into 14 lessons: measurement and unit systems; significant figures and powers of ten; arithmetic of scientific notation; vectors; graphs and motion; uniformly accelerated motion of bodies starting from rest; combining forces; laws of motion; universal gravitation; circular motion; impulse and momentum; work, energy, and power; internal energy, heat, and temperature; and gases, gas laws, and absolute temperature. An introductory statement to students is also included. Related documents are SE 015 964 through SE 015 977. (CC)

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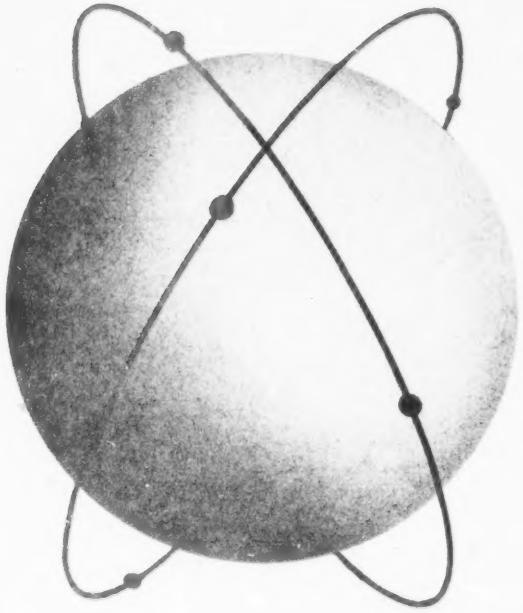

MBO LIST

NEW YORK INSTITUTE OF TECHNOLOGY
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Old Westbury, Long Island

New York, N.Y.

ARTICULATED MULTIMEDIA PHYSICS

MEASURABLE BEHAVIORAL OBJECTIVES

LESSONS 1 THROUGH 14

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ARTICULATED MULTIMEDIA PHYSICS

New York Institute of Technology
Old Westbury, N. Y.

To the student:

This list of MBO's (Measurable Behavioral Objectives) has been prepared for your use throughout the course. Essentially, an MBO tells you exactly what you are supposed to learn about every tiny aspect of every subject in physics. If you could meet the requirements of every objective listed in this booklet, you could then count on getting 100% on the final examination.

As you work through the STUDY GUIDE, the audio tapes, the films, the Worksheets, the homework, and the Post Tests, everything you do will be recorded as input for the N.Y.I.T. computer. The computer will analyze your work and report back information as to your progress, your strengths, and your weaknesses. Soon after you complete a lesson, you will receive a computer printout which tells you which MBO's you have not successfully achieved. This information will be provided to you in the form of MBO numbers which correspond with those given in this booklet. With this printout in your possession you may then at your leisure review and relearn the material specified in the MBO using any one or more of a group of sources such as textbooks, tapes, slides, films, and so on.

You should be familiar with the numbering code and other details related to the MBO's. We'll use the first MBO's on Page 1 of this booklet as examples.

Note that the very first numbered item (1.1) is a complete statement regarding the student's appreciation of the need for measuring tools, systems, and instruments. Any item containing two digits like this one is known as a terminal objective and is always a complete statement of what is required of the student in general terms.

Just below the first terminal objective is an item numbered 1.1.1. This is called an enabling objective. All enabling objectives carry three digits in the number. The first digit tells you the lesson to which it applies, the second digit tells you the terminal objective to which it belongs, and the last digit tells you the number of the enabling objective for that particular terminal objective.

Now, you'll notice that item 1.1.1 starts with some dashes like this "--- those statements which indicate the need for the measuring device in determining the comparative lengths of lines". Wherever you see dashes, you are to substitute the words, "Upon completion, the student must be able to select from a list of alternatives ...". Thus, enabling objective 1.1.1 should be read as "Upon completion, the student must be able to select from a list of alternatives those statements which indicate the need for a measuring device in determining the comparative lengths of lines." Since all the check

questions you will encounter in your work are the multiple choice type, you will always be selecting the right answer from a list of alternatives.

You can see that sometimes several questions in your STUDY GUIDE are used to test the same enabling objective. On Page 1, this is true of questions 2 and 3 in the left column, both of which apply to the same enabling objective 1.1.1. These are question numbers you will come to in Lesson 1 of the STUDY GUIDE.

Please bear in mind at all times that proper use of the MBO List in conjunction with the information you receive from the computer will be of great help to you in your studies. When you once correct a mistake by relearning, you will seldom make the same mistake again.

The staff of N.Y.I.T. wishes you the best of luck in your course in Articulated Multimedia Physics.

LESSON 1

	1.1	Upon completion, the student must be able to demonstrate that he appreciates the need for measuring tools, systems, and instruments in science.
1	1.1.1	--- those statements which indicate the need for a measuring device in determining the comparative lengths of lines.
2	1.1.1	
3	1.1.1	
4	1.1.2	--- the statement which indicates the need for a unit in measuring length.
	1.2	Upon completion, the student must exhibit familiarity with the kinds and relationships of length units.
5	1.2.1	--- units which are and are not used to measure length.
6	1.2.2	--- the number of yards in a given fraction of a mile.
7	1.2.3	--- the approximate number of feet in one meter.
8	1.2.4	--- the height of a good-sized man in meters.
9	1.2.5	--- correct conversions from one length unit to another in the metric system.
10	1.2.5	
11	1.2.5	
	1.3	Upon completion, the student must be able to multiply and divide units in equations to establish dimensions of an answer, or show dimensionsal consistency.
12	1.3.1	--- the statement which indicates correct handling of units in a simple metric conversion.
13	1.3.2	-- the correct answer to a simple cancellation problem in arithmetic (secondary branch).
14	1.3.1	
15	1.3.1	
16	1.3.3	--- the correct answer for a metric conversion problem of secondary difficulty (involving at least three terms).

17	1.3.1	
18	1.3.3	
19	(Notebook Check)	
20	1.3.4	--- the number of feet in one meter.
21	1.3.5	--- the number of kilometers per hour in 60 miles per hour
22	1.3.6	--- correct and incorrect groups of conversion problems, metric to English and vice versa.
	1.4	Upon completion, the student must exhibit familiarity with the kinds and relationships of time units.
23	1.4.1	--- the number of seconds in one hour of time.
24	1.4.2	--- the number of hours in a given interval of time.
25	1.4.2	
	1.5	Upon completion, the student must display an understanding of mass units, and the most basic relationship between mass and weight (proportionality).
26	1.5.1	--- the shortcoming of the definition of mass which states that mass is the quantity of matter in a body
27	1.5.2	--- the change of mass of a body whose weight is increased by a factor of 10.
28	1.5.3	--- the change of weight of a body whose mass is changed by a stated factor.
29	1.5.4	--- the correct statement relating to the fact that mass is constant but weight is variable.
30	1.5.5	--- determine the weight in pounds of a mass given in kilograms.
31	1.5.6	--- the correct number of grams which will have a given weight in pounds.
32	1.5.7	--- the group of mass conversions which contains all correct operations (as against groups which contain errors).
33	1.5.8	--- the correct reason for the discrepancy between a count of pulse beats in 60 seconds and the result obtained when the number of pulse beats counted in 10 seconds is multiplied by 6.

	1.6	Upon completion, the student must be able to answer descriptive questions relating to the krypton wavelength standard for the meter.
AV 1	1.6.1	--- the scientist who first suggested the use of light wavelengths to define the meter.
AV 2	1.6.2	--- the gas used for spectroscopically defining the standard meter.
AV 3	1.6.3	--- the country in which the standard meter is preserved.
AV 4	1.6.4	--- a triangular glass prism as the device which may be used to disperse light.
AV 5	1.6.5	--- the statement which gives the main shortcoming of the terrestrial method for defining the standard meter.
	1.7	Upon completion, the student must be able to solve simple numerical and literal problems involving the reciprocal of a number or a symbol.
AV 6	1.7.1	--- 0.1 as the reciprocal of 10.
AV 7	1.7.2	--- the definition of the reciprocal of a number as "one over the number."
AV 8	1.7.3	--- the reciprocal of the product xy as 1/xy.
AV 9	1.7.4	--- the reciprocal of m^2/sec as sec/m^2.
	1.8	Upon completion, the student must be able to answer qualitative questions relating to the mean solar day, mean solar year, and mean solar second.
AV 10	1.8.1	--- the number of seconds in a mean solar day.
AV 11	1.8.2	--- the statement that the time required for one rotation of the earth on its axis is very slowly increasing as a true statement from among a number of false statements regarding the earth as a time standard.
AV 12	1.8.3	--- the fact that the mean solar second as a basic time unit is now being replaced by a unit based on the vibrations of subatomic particles.
	1.9	Upon completion, the student must be able to answer elementary questions relating to the difference between mass and weight.
AV 13	1.9.1	--- the fact that a stone on the surface of the moon has the same mass as on earth but a different weight.

AV 14	1.9.2	--- the weight on the moon of a boy who weighs 120 lb on earth.
AV 15	1.9.3	--- a true statement relating to mass and weight from a number of false statements.
	1.10	Upon completion, the student must be able to answer descriptive questions relating to parallax.
AV 16	1.10.1	--- the true statement that parallax may be minimized by taking the proper precautions from among a number of false statements about parallax.
AV 17	1.10.2	--- the apparent motion of one of two pencils in line when the head is moved to one side or the other.
AV 18	1.10.3	--- the reason which best explains why a very thin metal tape does not cause much parallactic error in making a length measurement.

LESSON 2

	2.1	Upon completion, the student must be able to specify the number of significant figures in a given measurement
1	2.1.1	--- the most nearly correct estimate of the length of a block measured by a centimeter rule.
2, 3	2.1.2	--- the error that he made in an estimate of the length of a block measured by a centimeter rule.
4	2.1.3	--- the most nearly correct estimate of the height of the letter "E" in the word ONE on a U.S. dollar bill. (The ONE to which we refer is on the green side of the bill, printed across the center.)
5	2.1.4	--- the statement which indicates the limit of precision possible when a centimeter rule is used to measure the height of the "E" in the word ONE on a U.S. dollar bill.
6	2.1.5	--- the number which expresses the correct number of significant figures in the measurement 15.58 cm, or any other number similar to this.
7	2.1.6	--- the statement which indicates that the precision of a measurement does not depend on the measuring unit being used.
8	2.1.6	

9	2.1.7	--- the correct number of significant figures in a number such as 304, or one similar (i.e. with a zero between two non-zero digits).
10	2.1.8	--- the correct number of significant figures in a number such as 14.0 (i.e. with a zero after the decimal point.)
11	2.1.9	--- the correct number of significant figures in a number such as 37.00 (i.e. with two or more zeros after the decimal point).
12	2.1.10	--- the correct number of significant figures in a number such as 0.0845 (i.e. with one of more zeros between the decimal point and the next digit that is not a zero.)
13	2.1.11	--- the answer which indicates the understanding that when a number such as 186,272 is rounded back to 186,000, the zeros which replace the non-zero digits are not significant.
14	2.1.12	--- the correct number of significant figures in the answer when 299,792.8 km per sec is rounded back to 300,000 km per sec.
15	2.1.13	--- the group of numbers which is correctly described (with respect to the number of significant figures in each member of the group), as contrasted with other groups which are incorrectly analyzed.
	2.2	Upon completion, the student must be able to perform various arithmetic operations on measurements, assigning to the answer the correct number of significant figures as determined by the number of significant figures in each of the original pieces of data.
16	2.2.1	--- the correct sum of three length measurements without reducing the answer to the correct number of significant figures.
17	2.2.2	--- the statement which correctly indicates what should be done to the sum of three length measurements to establish the proper number of significant figures.
18	2.2.3	--- the correct sum of the previously given length measurements when each of the measurements is first rounded back to the appropriate number of significant figures.
19	2.2.2	--- see above.
20	2.2.3	--- the answer to a simple subtraction in which the correct number of significant figures is expressed.

21	-----	Notebook check.
22	2.2.4	--- the correct number of significant figures in the product of two length measurements, the calculation being an intermediate step (area) needed to find the volume of a parallelopiped.
23	2.2.5	--- the answer to a volume problem which has the correct number of significant figures.
24	2.2.6	--- the answer which best expresses the number of significant figures in a division problem.
25	2.2.7	--- the group of operations in which the number of significant figures in each answer in the group is correct. (The individual parts should contain examples of addition, subtraction, multiplication, and division).
26	-----	Notebook check.
	2.3	Upon completion, the student must be able to write any number in scientific notation (exponential notation in which the decimal point is always placed immediately after the first digit of the coefficient.)
27	2.3.1	--- the power to which 10 should be raised to yield a number such as 100,000,000.
28	2.3.2	--- the correct power of ten which expresses a quantity like ten billion.
29	2.3.3	--- the correct answer for expressing a number such as 600,000 in scientific notation.
30	2.3.4	--- the correct group of numbers all of which are properly expressed in scientific notation.
31	2.3.5	--- the correct expression for 6,450,000 in scientific notation to three significant figures.
32	2.3.6	--- the correct answer to a one-step problem involving the expression of a number in scientific notation.
33	2.3.7	--- the correct expression for one-billionth written in scientific notation.
34	2.3.8	--- the correct expression for 0.074483 written in scientific notation.
35	2.3.9	--- the group in which all the numbers (examples of numbers greater and less than unity) are properly written in scientific notation.
36	2.3.10	--- the statement which shows how a number like 5,000

		would be written in scientific notation to show that it contained 4 significant figures.
37	2.3.11	--- the answer which shows the correct way to round back 299,792.8 km/sec to three significant figures as shown by the scientific notation used.
	2.4	Upon completion, the student must be able to "round back" numbers to a given number of significant figures.
AV 1	2.4.1	--- the correctly "rounded back" number when given the desired number of significant figures to be contained in the final form.
	2.5	Upon completion, the student must be able to answer questions involving conversions from angstrom units to metric units, and vice versa.
AV 2	2.5.1	--- express a given wavelength of light in centimeters when it is initially stated in angstroms.
AV 3	2.5.2	--- recognize the angstrom unit from a verbal description of it when this description is embedded among other incorrect ones.
AV 4	2.1.14	--- the correct description of the measurement of the length of a U.S. dollar bill
	2.5	Upon completion, the student must be able to determine the mean of a series of measurements.
AV 5	2.5.1	--- the correct value of the mean of three measurements of the length of a dollar bill.
AV 6	2.5.1	
	2.6	Upon completion, the student must be able to give the method whereby one determines the number of significant digits in a number which ends in one or more zeros.
AV 7	2.6.1	--- the answer which shows that he understands that, when a number ends in zero and is not followed by a decimal point, the number of significant digits is indeterminate.
AV 8	2.6.1	
AV 9	2.6.2	--- the answer which shows that he knows that, when a decimal point follows the last zero of a number, the number of significant digits is equal to the total number of digits present.
	2.7	Upon completion, the student must be able to list the advantages of scientific notation over ordinary arithmetic notation.

AV 10	2.7.1	--- the one statement among others which is not an advantage of scientific notation.
AV 11	2.3.5	
AV 12	2.3.8	
	2.8	Upon completion, the student must be able to state the ordinary equivalent of several numbers raised to the first power and the zero power. The intent is to be sure he knows that any number raised to the zero power equals unity.
AV 13	2.8.1	--- the correct ordinary equivalent of a simple number raised to the first power
AV 14	2.8.2	--- the correct ordinary equivalent of a simple number raised to the zero power
AV 15	2.8.3	--- the correct answer for zero raised to the first (or any) power

LESSON 3

The Arithmetic of Scientific Notation

	3.1	Upon completion, the students must be able to multiply numbers expressed in scientific notation with proper attention to significant figures.
1	3.1.1	--- the correct name for the "6.5" part of a number such as 6.5×10^3.
2	3.1.2	--- the statement "adding the exponents" as the correct method to be used when multiplying two powers of ten (without coefficients).
3	3.1.3	--- the correct answer to a simple problem such as $10^2 \times 10^4$ as 10^6.
4	3.1.4	--- the correct answer to a simple problem in which coefficients must be multiplied and exponents added to arrive at the result.
5	3.1.5	--- the correct number of significant digits in the product of two weight or mass measurements, both measurements being properly expressed in scientific notation.
6	3.1.6	--- the area, to the correct number of significant figures, of a rectangle whose length and width are properly stated in scientific notation.

7	3.1.7	--- a solution of a problem involving the product of two numbers expressed in scientific notation, this solution containing an error while the rest of the alternatives are correct.
	3.2	Upon completion, the student must be able to express in scientific notation the square of a number which is itself expressed in scientific notation, with proper attention to significant figures.
8	3.2.1	--- the square of 25,000 mi when all the alternatives are expressed in scientific notation, the answer being correct to three significant digits. All alternatives have positive exponents.
9	3.2.2	--- the group of problem solutions which is completely correct, each group containing at least three different problems some of which are squares of numbers having positive and negative exponents.
	3.3	Upon completion, the student must be able to divide one number by another when both (or either) of the two original numbers are expressed in scientific notation.
10	3.3.1	--- the statement indicating that, when one power of ten is divided by another, the exponent of the divisor is subtracted from the exponent of the subtrahend.
11	3.3.2	--- the statement indicating that, when one number having a coefficient and a power of ten is to be divided by another similarly constructed number, the coefficients are to be divided while the final power of ten is obtained by exponent subtraction.
12	3.3.3	--- the incorrect solution to a group of problems when all the alternatives are correct except the one to be selected.
13	-----	Notebook check.
	3.4	Upon completion, the student must be able to find the square root of a number expressed in scientific notation with proper attention to significant figures.
14	3.4.1	--- the square root of a simple number like 9×10^{16}.
15	3.4.2	--- the square root of a number having a power of 10 with an odd exponent, positive in sign.
16	3.4.3	--- the square root of a number having a power of 10 with a negative exponent, either odd or even.
	3.5	Upon completion, the student must be able to find the

		sum of a group of numbers expressed in scientific notation whether or not their exponents are the same.
17	3.5.1	--- the group of ordinary numbers, arranged for finding the sum, in which the numbers are properly columnized for addition.
18	3.5.2	--- the correct sum of at least three numbers with different power-of-ten exponents, all expressed in scientific notation.
19	3.5.3	--- the correctly solved addition problem, the group to be evaluated consisting of numbers in scientific notation.
	3.6	Upon completion, the student must be able to express any measurement in terms of its order of magnitude.
20	3.6.1	--- the order of magnitude of 240,000 mi, approximately the distance from the earth to the moon.
21	3.6.2	--- the order of magnitude of the radius of an electron orbit in a normal hydrogen atom, i.e., 5.294×10^{-10} m.
	3.7	Upon completion, the student must be able to state how many times greater is the order of magnitude of a given measurement than another.
22	3.7.1	--- the number of orders of magnitude greater is the time since earliest man than the human life span, using a table of time intervals in which both of these are given (10^{13} compared with 10^{9}).
23	3.7.2	--- the number of orders of magnitude difference between the duration of a baseball game (10^{4} sec) and the time for an electric fan to turn once (10^{-2} sec).
24	3.7.3	--- the correct range of a complete table of orders of magnitude going from 10^{-22} sec to 10^{17} sec.
	3.8	Upon completion, the student must be able to answer questions relative to the importance of accurate arithmetic in the study of physics.
AV 1	3.8.1	--- the valid statement which says that one does not have to have a mind like a high-speed computer to become a physicist.
AV 2	3.8.2	--- the statement which indicates that reasonable accuracy in handling arithmetic is required to understand and apply concepts in physics.
AV 3	3.8.3	--- the scientist who is said to have had trouble with

high school geometry.

	3.9	Upon completion, the student must be able to raise numbers expressed in scientific notation (coefficient and power of ten) to powers higher than the square.
AV 4	3.9.1	--- the correct unit for the volume of a sphere when given the unit for the radius of the sphere.
AV 5	3.9.2	--- the correct expansion of $(z \times y^a)^b$.
AV 6	3.9.3	--- the correct expansion of a number such as $(4.20 \times 10^5)^3$.
	3.10	Upon completion, the student must be able to write the root of a number or symbol in fractional notation.
AV 7	3.10.1	--- the correct form of the cube root of a quantity such as (n + 2) in fractional notation.
AV 8	3.10.2	--- the correct form of the fifth root of a quantity such as Z in fractional notation.
AV 9	3.1.3	--- the product of $(25)^{\frac{1}{2}} \times (81)^{\frac{1}{2}}$. (This MBO number is not an error. It is actually 3.1.3, not 3.10.3).
	3.11	Upon completion, the student must be able to state the shortcoming with respect to retaining significant digits of subtracting two almost identical numbers.
AV 10	3.11.1	--- subtraction as the process that should be avoided for the sake of meaningful significant digits, if the two measurements are nearly alike.
AV 11	3.11.2	--- the statement which describes how the difference between two almost identical length measurements should be obtained without losing significant digits.
AV 12	3.7.4	--- the statement which shows that he has listened to tape segment 5 of Lesson 3 carefully enough to know that no mention was made of the method used by physicists to measure the time for one rotation of a proton on its axis. All the other statements were discussed in this segment.
AV 13	3.7.5	--- the general method used to measure time intervals having an order of magnitude below 10^{-10} sec as involving vibration rates of subatomic particles.
AV 14	3.7.6	--- the difference in order of magnitude between the time required to wind a wristwatch and the time required to wind a grandfather clock when the intervals are given, respectively, as 10 sec and 20 sec.

LESSON 4

Vectors

	4.1	Upon completion, the student must be able to recognize and differentiate between vector and scalar quantities.
1	4.1.1	--- the displacement resulting from a series of sequential trips for which magnitudes and directions are specified.
2	4.1.2	--- both the trip length and the displacement resulting from a series of sequential trips for which magnitudes and directions are specified.
3	4.1.3	--- the accepted method of measuring angles in a rectangular coordinate system, i.e., counterclockwise from the positive x-axis.
4	4.1.4	--- the number of kilometers represented by a vector for which a specific scale for the graphical method of representation is given.
5	4.1.4	----------
6	4.1.1	----------
	4.2	Upon completion, the student must be able to add vectors graphically using the closed triangle (or polygon) method, for rectangular components.
7	4.2.1	--- the correct displacement of a single trip from the length of the vector arrow and the given scale.
8	4.2.2	--- the total displacement from a set of given displacements by closing the triangle (graphical method).
9	4.2.3	--- the total displacement of a car that goes 45.0 km due east, then 105 km due north from a self-constructed vector diagram.
10	=====	Notebook check.
	4.3	Upon completion, the student must be able to add vectors which form special triangles by geometric methods. (Rt. $\triangle$'s).
11	4.3.1	--- the total displacement when the component displacements form the legs of a 3:4:5 triangle.
12	4.3.2	--- the total displacement when the component displacements form the legs of a 5:12:13 triangle.

	4.4	Upon completion, the student must be able to add vectors graphically at any angle using the polygon method.
13	4.4.1	--- the correct total displacement of two trips when the direction of the component displacements form an obtuse angle.
14	4.4.2	--- the diagram which shows the correct head-to-tail method for setting up a vector diagram involving an addition of two components.
15	4.4.2	---
	4.5	Upon completion, the student must be able to find the vector difference between two component vectors graphically.
16	4.5.1	--- the difference between two collinear vector displacements shown in diagram form.
17	4.5.2	--- the expression $\vec{V} + (-\vec{U})$ as the correct form for writing "$\vec{U}$ is to be subtracted from $\vec{V}$."
18	4.5.3	--- the statement which correctly expresses the rule violation committed when one vector displacement is subtracted from another by connecting to two tails of the components together instead of the proper head-to-tail connection.
19	4.5.4	--- the diagram showing correct method to be used to establish the proper head-to-tail connection for vector subtraction.
20	4.5.5	--- the geometric theorem which explains why the proper head-to-tail connection gives the same answer as the tail-to-tail "shortcut" (rule violation) for the subtraction of two vectors.
21	4.5.6	--- the diagrams which properly show how the vector arrows must be moved about to establish the correct vector picture for subtraction. (Two diagrams must be chosen).
	4.6	Upon completion, the student must be able to apply the techniques described in terminal objectives 4.1 through 4.5 to other vectors beside displacement.
22	4.6.1	--- the statement which affirms that the wind direction must be known if we are to determine the resultant velocity of an airplane moving with a given velocity in a wind of given magnitude.
23	4.6.2	--- the statement which shows that he knows that a

		direction must be given if a velocity is to be described.
24	-------	Notebook check.
25	4.6.3	--- a suitable scale for solving a problem in which the velocity of an airplane is given (speed and direction) with respect to the air, the velocity of the wind is given with respect to the ground, and the resultant velocity of the plane with respect to the ground is to be determined.
26	4.6.4	--- the correct velocity of the plane of problem 25 relative to the ground, after having drawn the vector diagram to scale.
	4.7	Upon completion, the student must be able to resolve a given vector into two rectangular components.
27	4.7.1	--- the correct answer to the question "...can a vector be resolved into two components by working backwards?" (The criterion check for this MBO would take the form of a pair of diagrams.)
28	4.7.2	--- the answer which indicates understanding that a given vector may have an infinite number of possible pairs of components.
29	4.7.2	----------
30	4.7.3	--- the required information that is missing from the directions: "--- find the comporents of the velocity v ---".
31	4.7.4	--- the diagram showing a given vector properly resolved into horizontal and vertical components.
32	4.7.5	--- the vector which correctly shows the velocity of the stream in a problem such as this: a swimmer heading directly across a stream with a given velocity is carried upstream by the current. His direction (resultant) relative to the bank is given. (The criterion check is based on an incomplete diagram).
33	4.7.6	--- the correct velocity of the stream to two significant digits.
AV 1	4.1.5	--- the product of a scalar quantity and a vector quantity.
AV 2	4.1.6	--- the statement which affirms that the time and direction of a given speed must be known if the resulting displacement is to be calculated.

AV 3	4.1.7	--- the fact that weight is a vector quantity.
	4.8	Upon completion, the student must be able to find the resultant displacement of a series of at least three displacements at angles other than 90 degrees and zero degrees.
AV 4	4.8.1	--- the answer which indicates understanding of the fact that the resultant displacement of two displacements at 180 degrees to one another is merely the arithmetic difference between them.
AV 5	4.8.2	---the net displacement of two given displacements at 30 degrees to one another.
AV 6	4.8.3	--- the net displacement of three given displacements at various angles to one another. (Note: 90 degrees may be one of the angles, but no more than one.)
AV 7	4.8.4	--- the distance between two towns (magnitude) when the displacements to these two towns from some common point of origin is given.
AV 8	4.8.5	--- the compass direction one would have to follow to go from one town to the other, data as in AV 7.
	4.9	Upon completion, the student must be able to answer questions relating to the details of the single-concept film entitled "The Velocity Vector".
AV 9	4.9.1	--- that which controls the speed and direction of the moving spot in the film.
AV 10	4.9.2	--- the answer which indicates that the legnth of the vector arrow on the screen of the computer is proportional to the speed of the moving spot.
AV 11	4.9.3	--- the fact that, for any given vector displayed on the screen, the velocity of the moving spot was constant.
	4.10	Upon completion, the student must be able to solve a problem involving the angle that a boat must head upstream under given conditions of boat speed and stream velocity, in order to reach the point directly opposite on the remote bank.
AV 12	4.10.1	--- that the boat's heading angle at the start of the problem has not yet been determined (based on a diagram).
AV 13	4.10.2	--- the fact that the point on the straight line across the stream where the boat is assumed to be for the purpose of drawing the vector diagram must be on the line but need

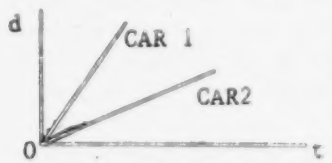
not be any specific distance from either bank.

AV 14	4.10.3	--- the correct heading angle upstream that the pilot must take for the conditions given in the problem.
AV 15	4.10.4	--- the correct speed of the boat at the angle selected in AV 14 for the conditions given in the problem.

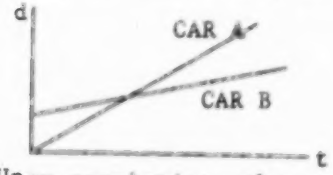
LESSON 5

Graphs of Motion

	5.1	Upon completion, the student must be able to solve simple problems using d = vt (d = displacement, v = speed, t = time) for bodies in uniform motion.
1	5.1.1	--- the distance covered by an object in a given time, speed being given.
	5.2	Upon completion, the student must be able to draw and analyze speed-time (v-t) graphs for bodies moving with uniform speed.
2	5.2.1	--- the statement that indicates that he understands that a straight, horizontal v-t graph represents a body moving with constant speed.
3	5.2.2	--- the distance traveled by a car whose motion is shown in a straight, horizontal v-t graph, the time for the trip being shown on the graph.
4	5.2.3	--- the distance traveled by a car which moves at a certain uniform speed for a given time and then at a different uniform speed for a different given time.
5	5.2.4	--- the concept that, in finding the average of two quantities, the quantities have to be properly weighted if they are not based on identical measurements.
6	5.2.5	--- the distance covered by a body moving with uniform speed from the area under the v-t curve.
	5.3	Upon completion, the student must be able to draw and analyze v-t graphs for bodies moving with uniform acceleration.
7	5.3.1	--- working from a graph which has one section showing constant acceleration and a second section showing constant speed, the correct description of each of the two parts of the v-t curve.

8	5.3.2	--- the correct relationship between the final speed and the average speed of a body which starts from rest and accelerates uniformly.
9	5.3.3	--- the fact that the average velocity is <u>not</u> the final velocity divided by two <u>unless</u> the acceleration of the body is <u>uniform</u>.
	5.4	Upon completion, the student must be able to analyze and describe v-t graphs in which a body moves with non-uniform acceleration.
10	5.4.1	--- the statement that a curved, sloping v-t graph indicates non-uniform acceleration.
11	5.4.2	--- the correct use of "delta-t" or Δt to describe an interval of time.
12	5.4.3	--- the correct symbolic statement which shows that if $\Delta t_a = \Delta t_b$ for a v-t graph of a body moving with constant acceleration, then $\Delta v_a = \Delta v_b$ for the same body.
13	5.4.4	--- the correct symbolic statement which shows that if $\Delta t_a = \Delta t_b$ for a v-t graph of a body moving with non-uniform acceleration, then $\Delta v_a \neq \Delta v_b$.
14	-----	Notebook check.
	5.5	Upon completion, the student must be able to analyze and describe distance-time graphs (d-t) in which a body moves with uniform speed.
15	5.5.1	--- the statement that car 1 has a higher speed than car 2 by analyzing a graph similar to that shown at the left in which the d-t relationships for two moving bodies are shown. 
16	5.5.2	--- in the form of four graphs, that graph which shows two objects moving with the same speed.
17	5.5.3	--- the relationship: slope = $\Delta d / \Delta t$ by examining a d-t curve for uniform speed in which the intervals are clearly marked.
18	5.5.4	--- the speed of car A as determined from a graph like that of 5.5.6 except that both axes are subdivided into units of time and units of distance, x-axis and y-axis respectively.
19	5.5.5	--- the speed of car B as determined from the same graph as in 5.5.6.

20 5.5.6 --- the distance the faster car (see graph below) had to go to catch the slower car.



The graph at the left is for use with MBO's 5.5.4 through 5.5.6. Note: units for t and d to be given.

5.6 Upon completion, the student must be able to analyze and draw d-t graphs for bodies which move in different directions successively along the same line with constant speed.

21 5.6.1 --- the statement which affirms that two collinear vectors in opposite directions are differentiated by means of (+) and (-) signs.

22 5.6.2 --- in the form of four graphs, that graph which correctly describes the motion of a car that goes from point A to point B, distance known, in a given time and returns to point A (taking a different time) along the same road.

23 5.6.3 --- the speed of a moving object whose motion is described by a labeled d-t graph having a negative slope.

24 5.6.4 --- the statement that, for a body whose speed is given as a negative quantity, the speed may be constant but its direction of motion is opposite that of the direction previously designated as positive.

5.7 Upon completion, the student must be able to recognize that a body is accelerating if its velocity changes with respect to time, the factors Δv and Δt being given either in a statement or in the form of a v-t graph; that slope = acceleration.

25 5.7.1 --- the correct answer to a problem which calls for determining acceleration when Δv and Δt are given.

26 5.7.2 --- the slope of a given v-t graph in general terms, that is, as $\Delta v / \Delta t$.

27 5.7.3 --- the correct answer to a problem in which initial speed, final speed, and elapsed time are given, to find the acceleration of the body.

5.8 Upon completion, the student must be able to state that, in plotting one variable against another in a graph, the independent variable should be shown on the x-axis and the dependent variable on the y-axis.

AV 1	5.8.1	--- the statement that force should be laid out on the x-axis when plotting acceleration of a constant mass against force.
AV 2	5.8.2	--- the statement that, when a graph is made to show how kinetic energy varies with velocity, the units for K.E. should be shown on the y-axis and the units for v on the x-axis.
	5.9	Upon completion, the student must be able to analyze a graph such as that on the Worksheet for Tape Segment 2, Lesson 5, describing the meaning of each portion of the curve.
AV 3	5.9.1	--- that a straight horizontal line segment in the referenced graph (v-t type) indicates constant speed.
AV 4	5.9.2	--- the fact that a straight line segment with a positive slope indicates uniformly increasing speed.
AV 5	5.9.3	--- the fact that a curved line segment connecting a straight line segment with positive slope to a straight line segment with zero slope indicates non-uniformly increasing speed.
AV 6	5.9.4	--- the fact that a curved line segment connecting a straight line segment of zero slope with a straight line segment of negative slope indicates non-uniformly decreasing speed.
AV 7	5.9.5	--- the fact that a straight line segment with a negative slope indicates uniformly decreasing speed.
AV 8	5.9.6	--- the fact that, in the referenced graph, the body moved with constant speed over the interval of longest duration shown on this graph.
	5.10	Upon completion, the student must be able to describe how instantaneous velocity on a d-t graph is found from the tangent to the curve at the point in question. (Ref. Worksheet for Tape Segment 3, Lesson 5).
AV 9	5.10.1	--- the fact that in Graph 2 of the referenced group, the portion that is straight and horizontal represents zero velocity on the d-t graph.
AV 10	5.10.2	--- the fact that in GRaph 2 of the referenced group, the average speed is larger over the interval which has the larger average slope.
AV 11	5.10.3	--- the fact that in Graph 3 of the referenced group, the slope of the tangent to the curve at a given point

indicates the instantaneous speed at that point.

5.11 Upon completion, the student must be able to state that a discontinuity in a d-t graph is a physical impossibility. (REF. graph on Worksheet for Tape Segment 4, Lesson 5).

AV 12 5.11.1 --- the time duration of the discontinuity in the referenced graph as zero.

AV 13 5.11.2 --- the statement which indicates that, when the d-t curve of a real object goes from a positive to a negative slope, the object must come to rest for a finite time.

AV 14 5.11.3 --- the fact that, if there is zero time between the recession of a body from the observer and the start of the re-approach to the observer, no time was allowed for the body to come to rest.

AV 15 5.11.4 --- the statement that a discontinuity in a distance time curve for a real object is a physical impossibility.

5.12 Upon completion, the student must be able to draw, recognize, and analyze the v-t and d-t curves describing the total trip motion of a ball given an initial velocity up an inclined plane and the return trip to the bottom of the plane.

AV 16 5.12.1 --- in the form of three graphs (Worksheet for Tape Segment 5, Lesson 5), the graph that correctly represents the total trip of the ball up and down the inclined plane, velocity vs. time.

AV 17 5.12.2 --- in the form of three graphs (same ref), the graph that correctly represents the total trip of the ball up and down the inclined plane, distance vs. time.

LESSON 6

Uniformly Accelerated Motion of Bodies Starting from Rest

6.1 Upon completion, the student must be able to recognize, set up, and apply direct proportions to the solution of physical problems.

1 6.1.1 --- the fact that increasing the length of a rectangle from 1 cm to 8 cm will cause the area to increase by a factor of 8 if the width remains constant.

2 6.1.2 --- the fact that two quantities are directly propor-

tional if their ratio is a constant for all values of the independent variable and the corresponding values of the dependent variable.

3 6.1.3 --- the statement that, if $B = kA$ and if the value of A is reduced to 1/3 or its initial value, then the new B will be 1/3 as large as the original B.

4 6.1.4 --- the fact that the equation for the area of a circle $A = \pi r^2$, may be written as a proportionality by writing $A = kr^2$ where k is the constant of proportionality.

5 6.1.5 --- the fact that the area of a circle increases by a factor of 9 when the radius is tripled.

6.2 Upon completion, the student must be able to recognize, set up, and apply inverse proportions to the solution of physical problems.

6 6.2.1 --- the fact that the density of a given constant mass will become half of its initial value if the volume of the body is doubled.

7 6.2.2 --- the statement that I and R are inversely proportional if $I_1R_1 = I_2R_2 = I_3R_3 = \ldots$ and so on.

8 6.2.3 --- (remedial branch) the fact that the statement "I_1 times R_1 equals I_2 times R_2" may also be written as $I_1R_1 = I_2R_2$.

9 6.2.4 --- (remedial branch) the fact that I_1R_1 will have the same value as I_2R_2 if numerals are substituted for the symbols in the relation $I_1R_1 = I_2R_2$.

10 6.2.5 --- the statement which shows that he understands and can identify a direct proportion in contract with an inverse proportion from the symbolic statements of the proportionalities.

11 6.2.6 --- the fact that, given the equation $I = B/d^2$ in which I = intensity of illumination; B = brightness of light source; and d = separation distance between source and screen, we may say that the intensity of illumination is inversely proportional to the square of the distance, if the brightness is held constant.

6.3 Upon completion, the student must be able to derive the expression $v = at$ for bodies that accelerate uniformly from rest, and use it in solving appropriate problems.

12 6.3.1 --- in the form of four graphs (3 v-t and 1 d-t), the

		graph which describes the motion of a body which accelerates uniformly from rest.
13	6.3.2	--- the fact that for a body starting from rest Δv over a given time interval is numerically the same as the final velocity v.
14	6.3.3	--- the relation $a = v/t$ as the correct equation for the acceleration of a body which accelerates uniformly from rest, where a = acceleration, v = final velocity, and t = time during which acceleration occurred.
15	6.3.4	--- the answer 8 ft/sec^2 as the acceleration of a body which accelerates uniformly from rest and attains a final velocity of 24 ft/sec in 3 sec.
16	6.3.5	--- the correct answer to a problem in which the value of g is given in MKS units, and the time of free fall is given in seconds, to find the final velocity acquired by the body.
17	-----	Notebook check.
	6.4	Upon completion, the student must be able to derive and use in problem solving the expression $d = at^2/2$ as the distance through which a uniformly accelerating body will move if its acceleration is a, and the time of travel is t.
18	6.4.1	--- the expression $d = \frac{1}{2}vt$ as the correct equation obtained when $\vec{v} = d/t$ is equated with $\vec{v} = \frac{1}{2}v$ and the equation solved for d, symbols having usual meanings.
19	6.4.2	--- the expression $d = \frac{1}{2}at^2$ as the correct expression obtained when the quantity <u>at</u> is substituted for v in the equation $d = \frac{1}{2}vt$ as previously obtained.
20	6.4.3	--- the statement that $d = \frac{1}{2}at^2$ checks dimensionally when suitable units (MKS) are substituted for the symbols.
21	6.4.4	--- the expression $d = \frac{1}{2}at^2$ as the correct equation to be used in solving a problem in which are given the acceleration and the time of travel, to find the distance the moving object would cover if it accelerates uniformly for the given time, starting from rest.
22	6.4.5	--- the correct answer to a numerical problem in which the uniform acceleration of a body is given, the time

		of travel is given, to find the distance traveled after starting from rest.
23	6.4.6	--- the correct answer to a numerical problem in which the initial speed of a moving body is given, the deceleration (uniform) of the body is given, to find the time required to bring it to rest.
24	6.4.7	--- the implication that the equation $d = \frac{1}{2}at^2$ expresses a direct proportionality between d and time squared.
25	6.4.8	--- the statement which shows that he can analyze a table showing trip length (d) against time (t) for a body moving with uniform acceleration from rest to extract the response that distance is directly proportional to the square of the time.
26	6.4.7	--- (remedial branch).
27	6.4.9	--- (remedial branch) --- that, since $k = d/t^2$ for constant acceleration, the proportionality which must exist between d and t^2 is a direct one. (constant ratio).
28	6.4.10	--- the correct answer to a numerical problem in which the distance traveled by a uniformly accelerating body and the time of travel are given, to find the distance traveled at the end of a given additional time interval. (Acceleration not given, but assumed constant).
29	6.4.10	--- similar example as above.
30	6.4.11	--- the correct answer to a problem in which the height of a building is given from which a ball is dropped with acceleration = g, to find the distance from the ground of the ball at the end of a given (sufficiently short) time interval.
31	6.4.12	--- the correct method to use in solving a problem in which the student is required to find the distance the object in 6.4.11 fell during a specific second.
32	6.4.13	--- (remedial branch) the statement that one really determines the distance of the object from the ground at the end of a specific time interval if he subtracts the distance fallen during that interval from the height of the building. (See 6.4.11).
33	6.4.14	--- the equation $t = \sqrt{2d/a}$ as the correct solution obtained when $d = \frac{1}{2}at^2$ is solved for t.
	6.5	Upon completion, the student must be able to solve problems in uniformly accelerated motion starting

from rest in which (1) time must first be found, given acceleration and initial velocity, for an object to reach the highest point of vertical flight and then (2) the altitude to which it will rise in vertical flight must be calculated.

34 6.5.1 --- the statement which correctly identifies the initial and final velocities in the rise path of an object thrown straight up from a diagram of the rise and fall of such an object, fully labeled.

35 6.5.2 --- the correct numerical answer to a problem in which rise time is to be found for a body thrown vertically upward, given the initial velocity and the negative acceleration. (British units).

36 6.5.3 --- the correct numerical answer to the problem proposed in 6.5.2, this time to find the maximum height to which the object rose.

37 6.5.4 --- the correct numerical answer to a problem in which both rise time and maximum height are to be found for an object thrown straight upward with a given initial velocity. (MKS units).

6.6 Upon completion, the student must be able to derive and use in problem solving the relation

$$v = \sqrt{2ad}$$

for bodies starting from rest and accelerating uniformly.

38 6.6.1 --- the fact that, if we want a single equation with which we can find the height to which a vertically thrown ball rises knowing only initial velocity and gravitational acceleration, then we must derive an equation which relates acceleration, distance, and velocity.

39 6.6.2 --- the statement that we must perform a dimensional check on a newly derived equation as a first test of its validity.

40 6.6.3 --- the statement that a dimensional check on $v^2 = 2ad$ shows that the equation is dimensionally valid.

41 6.6.4 --- the correct numerical answer to a problem in which the altitude from which an object is dropped (near the surface of the earth) is given, to find the velocity with which it reaches the earth, assuming no air resistance.

42 6.6.5 --- the incorrect statement which says that the final velocity of a body is directly proportional to the

		distance the body travels if the acceleration is constant.
43	6.6.6	--- the statement that the final velocity of a body moving with uniform acceleration will be 5 times as great if the distance through which it is allowed to move is 25 times as great as in some previous trial.
44	6.6.7	--- the correct numerical answer to a problem in which he is told that the distance through which a body in free fall is allowed to travel is increased six times as compared to some previous trial, to find the factor by which the final velocity has increased in the second trial.
AV 1	6.1.6	--- the number of Earth's that could be fitted into one Sun if the bodies could be brought together.
AV 2	6.1.7	--- the statement that the volume of a perfect sphere is directly proportional to the cube of its radius.
AV 3	6.1.8	--- the statement that neither the Earth nor the Sun is a perfect sphere.
AV 4	6.1.9	--- the correct answer to a problem in which two spherical volumes are given, to find the ratio of the diameters.
AV 5	6.1.10	--- the correct answer to a problem in which one side of each of two perfect cubes is given, to find the ratio of volumes.
	6.7	Upon completion, the student must be able to recognize a proportion in the form $y = k/x^2$ as the inverse square law and solve problems using this law.
AV 6	6.7.1	--- the correct answer to a problem in which the electrical force between two charged particles separated by a given distance is given, to determine the new distance which will reduce the forces to a definite fraction of it former value.
AV 7	6.7.2	--- the fact that the gravitational force between two point masses can be shown to follow the inverse square law.
AV 8	6.7.3	--- illumination intensity from a point source of light follows the inverse square law if the luminosity of the source is kept constant.
	6.8	Upon completion, the student must be able to recognize that g differs from place to place, and solve problems using various values of g.

AV 9	6.8.1	--- the value of the gravitational acceleration on the Moon in meters per second per second.
AV 10	6.8.2	--- the correct answer to a problem in which g for Jupiter is given, to find the time required for a body to fall a given distance to the surface of the planet from a relatively small altitude.
AV 11	6.8.3	--- the value of g in New York City in centimeters per second per second.
	6.9	Upon completion, the student must recognize and use the fact that, for an object thrown vertically upward, the time of rise to maximum height is equal to the time of fall to its origin.
AV 12	6.9.1	--- the statement that the time of rise to maximum height equals the time of fall back to origin.
AV 13	6.9.2	--- the correct answer to a problem in which the time is given for an ascent to maximum height and half-way back to origin (total time), to find the maximum height of ascent.
AV 14	6.9.3	--- the correct answer to a problem in which the time is given for a rise to maximum height and return, to find the initial upward velocity of the object thrown vertically upward.
	6.10	Upon completion, the student must be able to solve, in two different ways, a problem in which are given the length of a rifle barrel and the muzzle velocity of the bullet, to find the acceleration of the bullet while in the rifle.
AV 15	6.10.1	--- the correct equation to find the time of the bullet in the barrel knowing the length of the barrel and the muzzle velocity, but not knowing the acceleration.
AV 16	6.10.2	--- the answer which indicates that he knows the meaning of "d" in the average velocity equation, $d = \bar{v}t$, as applied to the rifle problem.
AV 17	6.10.3	--- the time spent in the barrel by the bullet as determined from $t = d/v$.
AV 18	6.10.4	--- the acceleration of the bullet in the rifle as determined from the given data and the time of the bullet in the rifle. ($a = v/t$ where v is final velocity).
AV 19	6.10.5	--- the acceleration of the bullet in the rifle by using the equation $v^2 = 2ad$ in a single-step solution.

LESSON 7

Combining Forces

	7.1	Upon completion, the student must be able to define a force as a push or pull, recognize its vector nature, and distinguish between contact forces and forces that act at a distance.
1	7.1.1	--- the fact that the action of a force may or may not produce a change in motion.
2	7.1.1	
3	7.1.2	--- the statement that force is always to be considered to be a vector quantity.
4	7.1.3	--- the fact that gravitation, as contrasted with a pull on a rope or the force of the wind, is a special kind of force, i.e., a force that acts at a distance.
	7.2	Upon completion, the student must be able to describe the conditions which must be met if a body is to be in either static or dynamic equilibrium.
5	7.2.1	--- a body initially at rest will not tend to move when acted upon simultaneously by a pair of equal and oppositely directed forces.
6	7.2.2	--- the fact that a body initially in motion with uniform velocity will not undergo a change of velocity if acted upon simultaneously by a pair of equal and oppositely directed forces.
7	7.2.3	--- the fact that a body acted upon simultaneously by <u>two</u> pairs of equal and oppositely directed forces will be in dynamic equilibrium if it had been moving with uniform velocity before the forces were applied.
	7.3	Upon completion, the student must be able to determine the net force or resultant of two or more collinear forces.
8	7.3.1	--- the statement that the net force, or resultant force, acting on a body is the arithmetic sum of the magnitudes of the individual component forces if the latter are collinear and in the same direction.
9	7.3.2	--- the positive and negative collinear forces in a diagram showing such forces acting on a common point, an arbitrary selection of the (+) direction having been made.

10	7.3.3	--- the correct value and direction of the net force of three given collinear forces.
11	7.3.4	--- given in the form of 4 diagrams showing various pairs of collinear forces, the diagram or diagrams which correctly show the net force of the system.
	7.4	Upon completion, the student must be able to determine the resultant of two given concurrent forces acting at angles other than zero or 180°.
12	7.4.1	--- the fact that the resultant force of two concurrent forces acting at an angle other than zero or 180° is <u>not</u> the arithmetic sum of the two forces.
13	7.4.2	--- (remedial branch) --- the fact that collinear forces act at either zero degrees or 180 degrees to one another.
14	7.4.3	--- the fact that the head-to-tail technique is the proper method for joining vectors in the addition process as we have learned it (polygon method).
15	7.4.4	--- a sensible scale to use in setting up the vector diagram for solving a specific problem in vector addition. (Boat being towed up a canal by ropes angled off to both banks).
16	7.4.5	--- the correct magnitude of the resultant force derived from the component forces acting at a given angle on the boat in the canal (See MBO 7.4.4).
17	7.4.6	--- the fact that an equilibrant in a given vector problem involving forces in equilibrium is equal in magnitude to the resultant but opposite in direction.
18	7.4.7	--- the right and wrong answers for a number of sets of forces in which the components are given as collinear forces and in which the equilibrant is to be determined in each case.
19	7.4.8	--- working from a diagram, the statement that the third force in a group of three concurrent forces in equilibrium is the equilibrant of the system when the components are at angles other than zero or 180 degrees.
20	7.4.9	--- the correct resultant in a problem in which two forces (concurrent) are given, the magnitudes and angles being stated, and the problem described as a situation in which the forces are applied by ropes tied to the same point on a sled.
21	7.4.10	--- the magnitude of the equilibrant for the system

		described in MBO 7.4.9.
22	7.4.11	--- the fact that, in a system in which two spring balances support a weight by means of two strings tied to one point on the weight, the sum of the balance readings is <u>not</u> equal to the hanging weight because the forces are not collinear.
23	7.4.11	--- (Remedial branch)
24	7.4.11	--- (Remedial branch)
25	7.4.12	--- the fact that any one of the three forces in the hanging weight problem (see MBO 7.4.11) may be considered to be the equilibrant for the other two forces.
26	7.4.13	--- the fact that, to find the resultant of the two spring balance forces in the hanging weight problem (see MBO 7.4.11), it would be best to consider the weight as the equilibrant of the spring balance forces.
	7.5	Upon completion, the student must be able to solve conceptual and functional problems, verbal or numerical, involving the resultant and equilibrant of various concurrent forces.
27	7.5.1	--- the statement that the equilibrant of a 5 lb force south and a 12.0 lb force east acting concurrently is 13 lb in some direction north of west.
28	7.5.2	--- the statement that the resultant of a very large force to the north acting on the same particle as a very small force to the east would be just a bit larger than 100 lb.
29	7.5.3	--- the statement that two forces must have the same magnitude if they are to make equal angles with their resultants.
30	7.5.4	--- the statement that the magnitude of a resultant must decrease if the angle between two concurrent forces increases.
	7.6	Upon completion, the student must be able to resolve any force into a pair of rectangular components.
31	7.6.1	--- the statement that the useful component of a force exerted on a sled by a rope at an angle to the ground is the forward component.
32	7.6.2	--- the correct numerical answer to a problem in which a given force is applied at a given angle to a sled

		by means of a rope, to find the magnitude of the useful component.
33	-----	Notebook check.
34	7.6.3	--- the fact that a boy can increase his useful component as he pulls on a sled-rope by lowering the rope to decrease the angle between it and the ground.
35	7.6.4	--- the force that a pupil needs to exert along a window pole held at a given angle to the window when the force needed to pull it straight down is also given.
36	7.6.5	--- the fact that in a typical horizontal boom problem, the tension in the angled cable may be taken as the equilibrant of the forces produced by the hanging weight and the thrust of the boom.
37	7.6.6	--- the fact that an object resting on a frictionless inclined plane will not remain on the slope if no external balancing force is used.
38	7.6.7	--- the fact that tilting a plane does not change the magnitude of the weight bearing down on the surface of the plane. (That is, $\underline{w}$ is constant regardless of plane angle.)
39	7.6.8	--- the fact that the weight $\underline{w}$ may be considered as the resultant of a force parallel to the plane and a force perpendicular to the plane (if these two forces are initially the components of $\underline{w}$).
40	7.6.9	--- the statement that the force causing sliding on an inclined plane increases while the force perpendicular to the plane decreases when the angle of the plane is increased.
41	7.6.10	--- the correct numerical answer to a problem relating to an inclined plane in which the angle of the plane and the weight of the sliding body are given, to find the force required to keep the body in equilibrium.
	7.7	Upon completion, the student must be able to answer a number of review questions dealing with a sequence of collinear displacements.
AV 1	7.7.1	--- the fact that the ant, according to DATA ITEM A, moved so as to produce collinear displacements.
AV 2	7.7.2	--- the correct vector sum of the two linear displacements. (DATA ITEM A)
AV 3	7.7.3	--- the correct resultant displacement of the

collinear displacements. (DATA ITEM A)

AV 4	7.7.4	--- the correct value and direction of the second displacement. (DATA ITEM A)
AV 5	7.7.5	--- the correct value and direction of a hypothetical second displacement which, together with the original first displacement, would yield a zero resultant. (DATA ITEM A).
AV 6	7.7.6	--- the correct value and direction of a hypothetical resultant if the second displacement had been +4 cm, the first displacement remaining the same. (DATA ITEM A)
	7.8	Upon completion, the student must be able to answer a number of questions relating to relative velocities in a problem involving a boat crossing a moving strem, given the data as in DATA ITEM B.
AV 7	7.8.1	--- the proper direction of the boat's apparent motion to an observer on a raft drifting downstream with current
AV 8	7.8.2	--- the proper direction of the boat's apparent motion relative to an observer on either bank.
AV 9	7.8.3	--- the correct speed of the boat with respect to an observer on either bank.
AV 10	7.8.4	--- the correct answer to the question as to what would happen to the relative speed of the boat to an observer on either bank if the speed of the stream were to double
AV 11	7.8.5	--- the new direction of the boat if the on-shore observer were to clock the boat at 10 mi/hr, the speed of the stream and boat relative to the water remaining the same
	7.9	--- Upon completion, the student must be able to answer a series of questions relating to the rectangular resolution of a given vector (DATA ITEM C).
AV 12	7.9.1	--- the statement that the given vector can be resolved into an infinite number of components if directions for resolution are not given.
AV 13	7.9.2	--- the correct value of the horizontal component of the given vector.
AV 14	7.9.3	--- the correct description of the change that would take place in each component if the angle between the vector and the horizontal axis were to be reduced.
	7.10	Upon completion, the student must be able to answer a

		series of questions relating to the conditions required for dynamic equilibrium.
AV 15	7.10.1	--- the force required to maintain a pair of specified collinear forces in equilibrium (dynamic).
AV 16	7.10.2	--- the answer which indicates that a body moving with uniform speed is in dynamic equilibrium only if it is moving in a straight line.
AV 17	7.10.3	--- the statement that shows that he understands why an earth satellite cannot be considered to be in dynamic equilibrium even when moving with constant speed.
AV 18	7.11	Upon completion, the student must be able to solve a verbal problem involving the effects which occur when a wire is stretched between two vertical supports, and the forces acting on the ends of the wires are increased so as to reduce the slack in the wire.
	7.12	Upon completion, the student must be able to answer a series of questions relating to a cable-and-boom problem (DATA ITEM B FOR TAPE SEGMENT 4).
AV 19	7.12.1	--- the fact that the thrust of the boom may be considered as the equilibrant of the system.
AV 20	7.12.2	--- the tension in the cable in the given problem.
AV 21	7.12.3	--- the force exerted by the boom at the point of support of the rope carrying the weight.

LESSON 8

The Laws of Motion

	8.1	Upon completion, the student must be able to define and use in the solution of problems all of the terms implicit in Newton's First Law of Motion, and understand their relationship with each other.
1	8.1.1	--- the correct reason why material objects do not start to move of their own volition.
2	8.1.2	--- the fact that the mass of a body is generally dependent upon the amount of matter contained in the body.
3	8.1.3	--- the fact that the mass of a body determines the magnitude of the inertia the body possesses.

4	8.1.4	--- the statement which best explains why the inertia experiment involving the sudden removal of a sheet of paper from under an object may not result in leaving the object behind, i.e., why the experiment might not work.
5	8.1.5	--- the direction in which you would tend to fall if you were standing in a stationary vehicle which suddenly began to move in a given direction.
6	8.1.6	--- the statement which best explains why you do not tend to fall at all when in a bus moving with uniform velocity.
7	8.1.7	--- the statement that a bus rounding a curve does not move with uniform velocity, even though its speed may be constant.
8	8.1.8	--- the direction in which you would tend to move when in a bus that is rounding a curve in a given direction.
	8.2	Upon completion, the student must be able to state and use Newton's Second Law of Motion in solving both verbal and numerical problems.
9	8.2.1	--- the statement that, if a force is applied for a short time to a body thus causing it to accelerate, when the force is removed the body will continue to move with constant velocity. (Unless otherwise stated, ideal conditions are assumed).
10	8.2.1	--- (Remedial branch)
11	8.2.2	--- the fact that the acceleration of a body will increase if the unbalanced force acting on it is increased.
12	8.2.3	--- the correct proportional relationship between acceleration and unbalanced force.
13	8.2.3	--- (Remedial branch)
14	8.2.4	--- the fact that two equal forces applied to two difference masses will cause the smaller mass to take on greater acceleration.
15	8.2.5	--- the statement that data given (for a constant force) relative to the accelerations of various masses indicates the existence of an inverse proportion between acceleration and mass.
16	8.2.5	--- (Remedial branch)

17	8.2.6	--- the correct method(s) of writing an inverse proportion symbolically.
18	-----	Notebook check.
19	8.2.7	--- the correct symbolic synthesis of the two separate proportions (i.e. $a = kF$ and $a = k'/m$) to form a single proportion which reads $a = kF/m$.
20	8.2.8	--- the best way of insuring that a model plane will fly when powered by a twisted rubber band, noting that mass should be reduced and driving force increased.
21	8.2.9	--- the statement that shows he remembers that a kilogram is a unit of mass.
22	8.2.10	--- the statement that the proportionality constant k in $a = kF/m$ becomes unity when the newton of force is defined as the force that will bring about an acceleration of 1 m/sec^2 when applied to a mass of 1 kg.
23	8.2.11	--- the expression $F = ma$ as the correct solution of $a = F/m$ when solved for F.
24	8.2.12	--- the correct solution to a one-step problem in which the mass and acceleration are given, to find the required unbalanced force (MKS).
25	8.2.13	--- the fact that, when units are substituted in $F = ma$ and the relation newtons = kilogram meters per second per second is obtained, this does not indicate that the units do not check.
26	8.2.14	--- the correct solution to a one-step problem in which the unbalanced force and the mass are given, to find the acceleration of the body (MKS).
27	8.2.15	--- the correct solution to a number of one-step problems in which force, mass, and acceleration are variously the unknown in a second law situation, the other required quantities being given.
	8.3	Upon completion, the student must be able to relate the restatement of the second law in gravitational terms (i.e. $w = mg$) to the solution of verbal and numerical problems involving weight, mass, and gravitational acceleration.
28	8.3.1	--- the fact that a body in free-fall near the surface of the earth accelerates uniformly. (Review.)
29	8.3.2	--- the newton as the correct unit of weight in the MKS system.

30	8.3.3	--- the fact that there are 4.5 nt in 1 lb.
31	8.3.4	--- the fact that, given the value of g on the Moon to be about 1/6 that on Earth, an object must weigh less on the Moon than it does on the Earth.
32	8.3.5	--- the fact that, when we specify that we are dealing with a "5-ton spaceship", we mean that its <u>weight</u> on Earth is 5 tons.
33	8.3.6	--- the best way to describe a force of -4.6×10^5 nt as a force of that magnitude directed oppositely to the motion.
34	8.2.16	--- the correct solution to a two-step problem involving the second law. In this problem, the separate masses of two bodies are first to be found from F and a, then the acceleration of the combined mass is to be determined given a known force.
	8.4	Upon completion, the student must be able to interpret situations and solve verbal and numerical problems involving Newton's Third Law of Motion.
35	8.4.1	--- correct explanation for the fact that a heavy object on which a large gravitational force acts does not move downward through the surface on which it rests
36	8.4.2	--- the correct analysis of a diagram showing a pair of reaction forces acting (erroneously) on a single particle. The student must be able to say that no particle could ever accelerate regardless of the size of the applied force if it was always being balanced by the reaction force.
37	8.4.3	--- the statement that, in a diagram showing a man pulling on a box to which he has tied a rope, there are two bodies involved.
38	8.4.4	--- the statement that, in the same diagram of the previous MBO, the two forces (action and reaction) are of equal magnitude, applied to two different bodies, and are opposite in direction.
39	8.4.5	--- the statement that, in a situation depicted by a diagram showing a 5 nt wt supported by a string which goes around a frictionless pulley to a horizontally supported weightless balance, the force applied by the balance spring is also 5 nt and acts upward on the weight.
40	8.4.6	--- the statement that, in a situation where a man pulls his boat into shore (he is in the boat) by means

		of a rope tied to a stake on shore, the reaction force of the stake on the man is directed oppositely from his direction of pull.
41	8.4.7	--- the fact that two weightless balances connected to each other "in series", the lower balance supporting a weight of known magnitude, will both read the same and each will read themagnitude of the hanging weight.
AV 1	8.1.9	--- the fact that, of the 4 objects described in Tape Segment 1 of Lesson 8, the ping pong ball would be the most difficult to leave behind in the inertia experiment because it has little mass.
AV 2	8.1.10	--- the fact that, to perform the inertia experiment with wine glasses, the table cloth being pulled out from under them would have to have a virtually friction-free surface.
AV 3	8.1.11	--- the correct explanation for the fact that you would probably topple over if someone were to jerk a rug out from under your feet.
	8.5	Upon completion, the student must be able to recognize and distinguish between motional effects viewed from various frames of reference.
AV 4	8.5.1	--- the fact that a passenger riding in a fast train rounding a curve is not acted upon by any outward unbalanced force as observed by an observer in an outside stationary frame of reference.
AV 5	8.5.2	--- the Earth as the fixed frame of reference used for most of our laboratory experiments in physics.
AV 6	8.5.3	--- the correct description of the three vectors which show the forces acting on a rider in the ROTOR as shown in the brief film entitled INERTIAL FORCES - CENTRIPETAL ACCELERATION (See diagram for Question 6 on the Worksheet for Tape Segment 2 of Lesson 8).
	8.6	Upon completion, the student must be able to discuss the advantages of writing Newton's Second Law in the form in which a is the dependent variable ($a = F/m$), or where m is given as F/a.
AV 7	8.6.1	--- the reason why $a = F/m$ is a realistic way to write Newton's Second Law in terms of dependent and independent variables.
AV 8	8.6.2	--- the fact that mass may be defined as force per unit acceleration by rewriting the SEcond Law as $m = F/a$.

AV 9	8.6.3	--- the fact that writing $F = ma$ is just as correct as writing $a = F/m$.
	8.7	Upon completion, the student must be able to answer descriptive questions relating to the significance of, conditions prevailing for, and controlling factors for bodies which have reached terminal velocity in falling to earth.
AV 10	8.7.1	--- the fact that the value of gravitational acceleration for a body that has reached terminal velocity is zero.
AV 11	8.7.2	the fact that the speed of a body is constant at its terminal velocity.
AV 12	8.7.3	--- the statement that a falling body is in dynamic equilibrium when it has attained terminal velocity
AV 13	8.7.4	--- the fact that terminal velocity decreases for fluids having greater densities for a given body.
	8.8	Upon completion, the student must be able to select one of three given vector diagrams showing the forces acting on a passenger riding in an elevator which starts from rest, goes up to the 10th floor, then returns to its starting point on the first floor as shown in the brief film entitled INERTIAL FORCE - TRANSLATIONAL EQUILIBRIUM for each of the motions given in the enabling objectives below.
AV 14	8.8.1	--- the correct diagram for the elevator just starting on the "down trip."
AV 15	8.8.2	--- the correct diagram for the elevator at rest.
AV 16	8.8.3	--- the correct diagram for the situation where the elevator is being brought to rest at the end of the "down trip."
AV 17	8.8.4	--- the correct diagram for the situation where the elevator is being brought to rest at the end of the "up trip."
AV 18	8.8.5	--- the correct diagram for the conditions which occur just as the elevator starts on the "up trip."
AV 19	8.8.6	--- the correct diagram for the elevator descending at uniform speed.
AV 20	8.8.7	--- the correct diagram for the elevator ascending with constant speed.

LESSON 9

Universal Gravitation

	9.1	Upon completion, the student must recognize that if the distance between their centers is constant, the gravitational attractions between two bodies varies directly as the product of their masses, and must be able to solve verbal and numerical problems involving this concept.
1	9.1.1	--- a large "quantity" of matter has a correspondingly large mass. (Review)
2	9.1.2	--- the fact that two large masses have a greater gravitational attraction for one another than two small masses or one large and one small mass.
3	9.1.3	--- the correct interpretation of a table showing that the force of gravitation between two bodies is directly proportional to the product of their masses rather than the sum or quotient of the masses (with separation between centers constant.)
4	9.1.4	--- the fact that doubling each of two masses without changing their separation will result in a fourfold increase in gravitational attraction.
5	9.1.5	--- the fact that increasing the mass of an object, say a satellite, results in a proportional increase in the attraction of the Earth for this object if the separation remains constant.
	9.2	Upon completion, the student must recognize that the force of gravitation varies inversely as the square of the distance separating the centers of two masses, and must be able to solve verbal and functional numerical problems involving this concept.
6	9.2.1	--- the fact that is is reasonable to expect the force of gravitation between two bodies to decrease as they are moved further apart.
7	9.2.2	--- the relationship $F_g = k/r^2$ as the correct way to write the inverse proportion between gravitational attraction and the distance separating the centers of the two masses.
8	9.2.3	--- the correct answer to a functional problem in which the mass of one body is tripled and the other mass is quadrupled while the separation is doubled, to find the change in the gravitational force.

	9.3	Upon completion, the student must be able to state and apply to problem solutions the Law of Universal Gravitation in its most basic form. (Without G).
9	9.3.1	--- the satellite of Jupiter (either Io or Callisto) which experiences the greater force of gravitation due to nearness of the mother planet, given the separation distances and the mass ratio of the two satellites.
10	9.3.2	--- the range of ratios which correctly includes the ratio of the gravitational force acting on Io as compared to that acting on Callisto.
11	9.3.3	--- the fact that we want to be able to express gravitational force in newtons since this is the unit of force to which we are committed in the MKS system.
	9.4	Upon completion, the student must recognize that G is not unity nor dimensionless but has a definite value and a unit (derived) which will enable us to express gravitational force in newtons.
12	9.4.1	--- which describes the possible reasons why we cannot assume k in $F_g = m_1 m_2/r^2(k)$ to be dimensionless, the answer which indicates understanding of the significance of the failure of the dimensional check for $F_g = m_1 m_2/r^2$.
13	9.4.2	--- $m^3/kg\text{-}sec^2$ as the correct unit for G in the MKS system obtained by solving for G and substituting MKS units for the remaining terms.
14	9.4.3	--- the gravitational force in newtons between two 1 kg particles separated by 1 m if the value of G is assumed to be 1 $m^3/kg\text{-}sec^2$.
15	9.4.4	--- the fact that, in the Cavendish experiment, the observer can determine the values of m_1, m_2, r, and F_g, leaving only the constant of proportionality (G) as the unknown.
16	9.4.5	--- the correct value of G, given all the necessary data from the Cavendish experiment.
	9.5	Upon completion, the student must be able to explain why all masses fall with the same acceleration from the same point near the Earth's surface using Newton's Second Law and the Law of Universal Gravitation in the explanation.
17	9.5.1	--- the equation $g = F_g/m$ as the best statement of the Second Law as applied specifically to bodies in free fall.

18 9.5.2 --- the form $g = \frac{Gm_e}{r^2}$ as the correct simplification of:

$$g = \frac{\frac{Gm_om_e}{r^2}}{m_o}$$

(Note: this latter is obtained by substituting Gm_om_e/r^2 in place of F_g in the expression obtained in 9.5.1).

19 9.5.3 --- the correct interpretation of the simplification in 9.5.2 as the following: the acceleration of a freely falling body is independent of the mass of the body.

20 9.5.4 Remedial branch.

9.6 Upon completion, the student must be able to compute the mass of the Earth given the required data.

21 9.6.1 --- the correct set of substitutions of values on the right side of the equation

$$m_e = \frac{gr^2}{G}$$

9.7 Upon completion, the student must be able to find the weight of a man of given mass on the planet Mars.

22 9.7.1 --- the equation $w = G\frac{m_pm_m}{r^2}$ as the correct expression to use to find the weight of a person on Mars where m_p = mass of person, m_m = mass of Mars, r = the radius of Mars, and G is the universal constant of gravitation

23 9.7.2 --- the correct intermediate result for the problem of the terminal objective after substitutions have been made.

9.8 Upon completion, the student must be able to solve a problem involving the amount of weight lost by an object ascending a given distance above the Earth.

24 9.8.1 --- the following equation as the one which correctly expresses, in general terms, the conditions which obtain when an ascending rocket has risen high enough to lose half its weight:

$$\frac{w}{2} = G\frac{m_rm_e}{r^2}$$

in which w = the weight of the rocket on the Earth's surface, m_r = mass of rocket, m_e = mass of Earth, and r = distance of risen rocket from the center of the Earth. (Earth radius taken as 4000 mi).

25	9.8.2	--- the quantities m_e, G, and m_r as those which remain constant as the rocket of 9.8.1 rises.
26	9.8.3	--- the result $2 = \frac{r^2}{(4000)^2}$ which should be obtained when the sea level equation for the weight of the rocket, i.e. $w = \frac{k}{(4000)^2}$ is divided by the new altitude equation $\frac{w}{2} = \frac{k}{r^2}$
27	9.8.4	--- the result: $r = 1.41 \times 4000$ as the correct one to obtain when the equation $2 = \frac{r^2}{(4000)^2}$ is solved for r.
	9.9	Upon completion, the student must be able to explain how the air track experiment performed in the brief film "Newton's Third Law" serves to verify the third law.
AV 1	9.9.1	--- the statement that a glider which moves three times as far as another in the same time interval must have had three times the acceleration of the other.
AV 2	9.9.2	--- the fact that in any one of the trials shown in the film, the action force on one glider is equal to the reaction force on the other, and is opposite in direction
AV 3	9.9.3	--- the correct answer to a problem in which the relative glider masses are given, the acceleration of glider 2 being a', to find the acceleration of glider 1 in terms of a'. (See MBO 9.9).
	9.10	Upon completion, the student must be able to display an understanding of the universal nature of gravitation
AV 4	9.10.1	--- the statement that indicates he understands that the same law of gravitation that applies to bodies on or near the earth, also applies to planets and stars anywhere in the universe.
AV 5	9.10.2	--- the correct answer to a functional problem involving the placing of a body between two other bodies so that the former "feels" an equal gravitational attraction from each of the original two bodies.

AV 6	9.10.3	--- the fact that the Earth-Moon system comprises a pair of bodies for which gravitation exists as a pair of forces, F and -F, which follow the third law.
	9.11	Upon completion, the student must be able to answer questions relating to the Cavendish experiment as shown in the brief film "THE MEASUREMENT OF G - THE CAVENDISH EXPERIMENT."
AV 7	9.11.1	--- the statement that a light pointer is used in order to magnify the movement of the Cavendish "dumbell."
AV 8	9.11.2	--- the unit nt-m^2/kg^2 as another possible unit for G, the constant of universal gravitation.
	9.12	Upon completion, the student must be able to give a descriptive explanation for the independence of gravitational acceleration and mass of falling body.
AV 9	9.12.1	--- air resistance as the factor which causes a leaf to fall more slowly than an acorn.
AV 10	9.12.2	--- the statement that, for two balls of different material but the same diameter falling through air, it is FALSE to say that both balls are acted on by the same accelerating force.
AV 11	9.12.3	--- the correct definition of mass as force per unit acceleration.

LESSON 10

Circular Motion

	10.1	Upon completion, the student must be able to define and describe the instantaneous velocity of a particle moving in a circle, and relate the characteristics of this velocity to the centripetal force which causes changes in it to occur.
1	10.1.1	--- (Review) the fact that a body in dynamic equilibrium moves with uniform velocity.
2	10.1.2	--- the fact that a force acting at right angles to the line of motion of a particle can, when applied to the particle, cause the path to become a curve, the deviation continuing throughout the interval of force action.
3	10.1.3	--- as applied to a diagram showing straight and curved

paths of a given particle, the zero curvature portions of the path as those portions where no unbalanced force acts at right angles to the motion.

4 10.1.4 --- the fact that the curved path produced by a force acting on a particle at right angles to its path is part of a circle, provided that the magnitude of this force is constant.

5 10.1.5 --- the fact that a body moving in a curved path with constant speed does not move with constant velocity.

6 10.1.6 --- the statement that the angle between the instantaneous velocity vector drawn through a particle moving in a circle and the line of action of the force producing the curved path is always a right angle.

7 10.1.7 --- the statement that, if the centripetal force acting on a particle moving in a circle were to be removed, the particle would then move in a path that is tangent to the circle at the point corresponding to the removal of the force.

10.2 Upon completion, the student must be able to write and use in the solution of problems the relationship: $F = mv^2/r$ in which F is centripetal force, m is the mass of the rotating particle, v is its instantaneous tangential velocity, and r is the radius of rotation.

8 10.2.1 --- the statement that, as the speed of the rotating particle is increased, the centripetal force required to keep it in the same path also increases.

9 10.2.2 --- the statement that, for a particle whose tangential velocity is kept constant (by varying the angular velocity as required), as the radius of rotation decreases so must the centripetal force be required to increase.

10 10.2.3 --- the fact that more centripetal force is required to keep a body of large mass rotating in a given circle with a given speed than is required for a body of smaller mass.

11 10.2.4 --- the relation $F_c = kmv/r$ as the correct combined form of three proportions developed in the lesson, that is,

$$\left.\begin{array}{l} F_c = kv \\ F_c = k/r \\ \text{and } F_c = km \end{array}\right\} \text{ may be combined as } F_c = kmv/r$$

12 10.2.5 --- the fact that the combined proportional expression in 10.2.4 does <u>not</u> check dimensionally.

13	10.2.6	--- (Remedial)
14	10.2.7	--- the correct interpretation of a table of values showing a number of trials in an experiment in which one of the variables (m, v, and r) is allowed to vary while the others are held constant, the required centripetal force being shown in the table for each case.
15	10.2.8	--- the fact that the table of values (see 10.2.7) for the centripetal force experiment implies that the required force varies directly as the square of the instantaneous tangential velocity.
16	10.2.9	--- the statement that the constant of proportionality k in $F_c = kmv^2/r$ is dimensionless, the student to arrive at this conclusion by substituting units (MKS) for m, v, and r and noting that mv^2/r comes out in newtons if k is assumed to be dimensionless.
17	10.2.10	--- the correct answer to a numerical problem in which m, v, and r are given, to find the centripetal force.
18	10.2.11	--- the correct literal equation representing the relation $F_c = mv^2/r$ solved for v as the unknown.
19	10.2.12	--- the correct listing of the numerical values for m, r, v, and F_c extracted from a problem in which he is asked to find the maximum speed at which a particle may be whirled around, given the mass, radius, and force that will break the string. (The objective here is to be sure that the student can "set up" the data symbolically).
20	10.2.13	--- the correct final answer to the problem in which he is to find the maximum whirling speed given the mass, radius, and breaking force of the string.
21	10.2.14	--- the fact that, when a charged particle is caused to move in a circle in a magnetic field, the magnetic force must be acting at right angles to the tangent of the circle in which the particle moves. The student must recognize that the magnetic force is the centripetal force in this case.
22	10.2.15	--- the relation $m_p v_p^2 = m_e v_e^2$ (where subscript p is proton and subscript e is electron) as the correct equation for the condition in which the the same magnetic force is exerted on a proton and an electron causing both to move in circles of equal radii.

23 10.2.16 --- the statement that the centripetal force required to keep a proton moving in a circle of the same radius as an electron, and at the same speed, would be greater for the proton than for the electron.

24 ----- Notebook check.

10.3 Upon completion, the student must be able to describe centripetal acceleration with respect to both direction and magnitude, verbally and mathematically.

25 10.3.1 --- the statement that, since centripetal force acts toward the center of rotation, the particle on which the force acts must accelerate toward the center of rotation.

26 10.3.2 --- as shown in a diagram such as the one on the right, the fact that the particle was undergoing acceleration along path BC.

27 10.3.3 --- (Review) the relation $a = F/m$ as a general statement of Newton's Second Law of Motion.

28 10.3.4 --- the correct simplification of $a_c = \frac{mv^2/r}{m}$ in which a_c = centripetal acceleration as $a_c = v^2/r$.

10.4 Upon completion, the student must be able to state an elementary definition of center of gravity. (Note: this subject is merely mentioned and presented almost entirely in the form of a short linear program).

29 10.4.1 --- if a body with a finite set of dimensions moves in a circle, and if the body is symmetrical, the radius of rotation may be stated as the distance between the center of the circle and the <u>center</u> of the body.

10.5 Upon completion, the student must be able to derive the equation which shows the speed a satellite must have to stay in a predetermined circular orbit:

$$v = \sqrt{G \frac{m_e}{r}}$$

30 10.5.1 --- the statement that a body orbiting the Earth would take off in a tangential path if the gravitational force from the Earth did not exist.

31 10.5.2 --- (Review) the fact that m in the expression $F_c = mv^2/r$ as applied to satellite motion is the mass

of the satellite itself.

32 10.5.3 --- after having equated $m_s v^2/r$ and $Gm_s m_e/r^2$, the term v as the one which must be solved for if we are to obtain an equation which will state the speed the satellite must have to stay in orbit.

33 10.5.4 --- the form: $v = \sqrt{G\frac{m_e}{r}}$ as the correct solution of the equated terms in 10.5.3.

34 10.6 Upon completion, the student must be able to show that the mass of a satellite is not a factor in determining the velocity required to remain in orbit.

10.7 Upon completion, the student must be able to solve problems involving the equation in 10.5.4.

35 10.7.1 --- the statement that the speed at which a satellite must travel varies inversely as the square root of the radius of the orbit in which we want it to move.

36 10.7.2 --- the fact that, for a satellite orbiting at an altitude h, the radius of its orbit is $h + r_e$ where r_e is the radius of the Earth.

37 10.7.3 --- the fact that the speed of a satellite orbiting Mars at a given distance from the center of the planet would not be the same as that of a satellite orbiting Earth at the same distance from its center.

38 10.7.4 --- the statement that a Martian satellite would travel more slowly than an Earth satellite having the same orbital radius.

39 10.7.5 --- the fraction 1/3 as the approximate ratio of the speed of a Martian satellite to the speed of an Earth satellite orbiting with the same radius.

40 10.8 Upon completion, the student must be able to state that, in a system involving a ball whirling around at the end of a taut string, the centrifugal force is the outward force acting on the center of rotation not on the ball.

10.9 Upon completion, the student must be able to respond to questions relative to "centrifugal" force in a way such that he displays an understanding of it fictional nature as seen from a fixed frame of reference.

AV 1 10.9.1 --- a nearby star as a "fixed" frame of reference to be used in describing the forces acting in the Earth-Sun gravitational system.

AV 2	10.9.2	--- the Sun as a suitable fixed frame of reference from which to analyze the forces acting on the Apollo 8 spacecraft while in its first orbit around the Earth.
AV 3	10.9.3	--- the statement that one can build up a set of consistent physical laws based on centrifugal force only if one is inside the framework of the rotating system.
	10.10	Upon completion, the student must be able to show why the use of a horizontal "whirling" circle for, say, a stone on a string is specified in problems where one wants to eliminate all forces from consideration other than centripetal force.
AV 4	10.10.1	--- 90° as the angle made by a plumb line with a horizontal plane through which it passes.
AV 5	10.10.2	--- the statement that gravitation acts on the whirling particle while it is moving in <u>any</u> plane.
AV 6	10.10.3	--- the fact that, only when in a horizontal plane, can it be assumed that the centripetal force is equal for all instantaneous positions of the whirling particle.
	10.11	Upon completion, the student must be able to state that, if orbital radius were the only consideration, the innermost planet of the solar system would be subject to the greatest force while the outermost planet would be subject to the least.
AV 7	10.11.1	--- the statement that centripetal force is inversely proportional to the radius of rotation.
AV 8	10.11.2	--- Mercury as the planet which would have the largest centripetal force acting on it, and Pluto as the planet with the smallest if orbital radius were the only factor governing the magnitude of the centripetal force required to maintain orbit.
AV 9	10.12	Upon completion, the student must be able to solve a functional problem in which he must determine the orbital radius of an α-particle in terms of the radius of the orbit of a proton in a given magnetic field and traveling at the same speed as the proton.
	10.13	Upon completion, the student must be able to analyze a table of Solar System data for four planets and decide which set of data represents approximate orbital velocities and which represents approximate masses.

AV 10	10.13.1	--- the column of figures in the table of DATA ITEM A of the Worksheet for Tape Segment 5 which shows the approximate orbital velocities of the four planets listed.
AV 11	10.13.2	--- the column of figures, as above, which shows the masses of the four planets.
	10.14	Upon completion, the student must be able to describe and analyze the forces acting on a small wood block rotating on the surface of a phono turntable.
AV 12	10.14.1	--- the turntable as the body on which the centrifugal force acts, the direction being toward the rim of the disc.
AV 13	10.14.2	--- the fact that changing the direction of rotation would not affect the wood block, the turntable, the centripetal force, nor the centrifugal force.
	10.15	Upon completion, the student must be able to answer descriptive questions relating to the brief film THE VELOCITY AND ACCELERATION IN CIRCULAR MOTION.
AV 14	10.15.1	--- the fact that the velocity vector in circular motion has the same direction as the tangent.
AV 15	10.15.2	--- the fact that the acceleration vector is always perpendicular to the velocity vector.
AV 16	10.15.3	--- the fact that the acceleration vector always lies along a radius of the circle of rotation.

LESSON 11

Impulse and Momentum

	11.1	Upon completion, the student must be able to define impulse as the product $F\Delta t$, state the unit used for it, and recognize it as a vector quantity.
1	11.1.1	--- the fact that exerting a large force for a short time can accomplish the same effect on an object as exerting a small force for a proportionately longer time.
2	11.1.2	--- as applied to a set of data obtained from a hypothetical experiment, the statement that the product $F\Delta t$ for each of several trials in which the force produces an identical effect turns out to be identical.

3	11.1.3	--- the newton-second as the correct MKS unit for impulse, the product of F and Δt.
4	11.1.4	--- the statement which implies that a direction must be assigned to a specific impulse if we are to predict its effect, hence impulse is a vector quantity.
	11.2	Upon completion, the student must be able to solve fundamental problems involving the impulse of a force.
5	11.2.1	--- the impulse applied to a specific object by a given force acting for a given time, the time stated in minutes and the impulse to be found in newton-sec.
	11.3	Upon completion, the student must be able to define momentum as the product mv, give its MKS unit, and recognize it as a vector quantity.
6	11.3.1	--- the intuitive feeling that the "quantity of motion" as described in the text would increase by a factor of 4 if both the mass and the velocity of the moving body were to be doubled.
7	11.3.2	--- the statement that the depth to which a massive sharp-pointed moving object will penetrate into a piece of wood will depend on both the mass and velocity of the moving object.
8	11.3.3	--- the relation $p = mv$ as the correct one to define momentum, if p = momentum and m and v have their usual meanings.
9	11.3.4	--- the reason for stating that momentum is a vector quantity, namely, that the product of a scalar and a vector is a vector quantity.
10	11.3.5	--- the kg-m/sec as the correct unit for momentum in the MKS system.
	11.4	Upon completion, the student must be able to display understanding of the derviation of the equation $F\Delta t = m\Delta v$, and use this relationship to answer qualitative questions.
11	11.4.1	--- the expression $a = \Delta v/\Delta t$ as a general definition of acceleration (review).
12	11.4.2	--- the derived quantity $F\Delta t$ as an expression of impulse.
13	11.4.3	--- the derived quantity $m\Delta v$ as an expression of change of momentum.

14	11.4.4	--- the correct units for force, time, mass, and velocity in order to keep all problem work in $F\Delta t = m\Delta v$ in the MKS system.
	11.5	Upon completion, the student must be able to solve one or more problems involving impulse and momentum (numerical, with units).
15	11.5.1	--- the initial momentum of a ball that is thrown straight upward, given the mass of the ball in kg and the initial velocity of the ball in m/sec.
16	11.5.2	--- the impulse that was required to stop the ball at the top of its flight. (Ref 11.5.1).
17	11.5.3	--- the weight of the ball, knowing its mass. (Ref 11.5.1).
18	11.5.4	--- the time interval over which the force which caused the initial acceleration of the ball was applied. (Ref 11.5.1).
	11.6	Upon completion, the student must understand the use of (+) and (-) signs in expressing changes of velocity, and be able to solve numerical problems in this connection.
19	11.6.1	--- the proper negative quantity which expresses a decrease in velocity of a moving body.
20	11.6.2	--- the proper negative quantity which expresses the magnitude of the change of velocity when a moving body is caused to reverse its direction.
21	11.6.3	--- given the mass of a body, its constant velocity in one direction, the magnitude of a constant force in the opposite direction, and its final velocity in the direction of the force (a reversal of direction), to find the impulse acting on the body.
22	11.6.4	--- after finding the force involved in the above impulse to have a negative sign, the correct reason for this negative sign. (Ref 11.6.3).
23	11.6.5	--- the momentum possessed by the body after the impulse has acted. (Ref 11.6.3).
	11.7	Upon completion, the student must be able to state the principle of conservation of momentum in verbal and symbolic form as related to the "explosion" type of interaction.

24	11.7.1	--- the statement that the speed of each of two equal masses pushed apart by a common compressed spring when released between them is equal.
25	11.7.2	--- the fact that doubling one of the masses results in a decrease in the speed of this mass after release of the spring. (Ref 11.7.1).
26	11.7.3	--- given the masses and respective changes of velocity of the masses involved in an "explosion" interaction, the statement which shows that he has correctly combined these quantities to determine whether or not the conservation requirement has been met.
27	11.7.4	--- the expression $m_1\Delta v_1 = -m_2\Delta v_2$ as the correct equation for representing conservation of momentum in an "explosion" interaction of two masses.
28	11.7.5	--- the correct statement for explaining why the recoil velocity of a rifle is substantially less than the velocity of the bullet fired from this rifle.
29	11.7.6	--- the fact that the recoil velocity of a different rifle firing the same bullet is less because its mass is proportionately less. (Ref 11.7.5).
	11.8	Upon completion, the student must be able to transfer his understanding of conservation of momentum to the conditions involved in elastic and inelastic collisions.
30	11.8.1	--- given a diagram showing one billiard ball with a finite velocity v_1 approaching a second ball with a label "$v_2 = 0$", the statement that the ball with the $v_2 = 0$ label is at rest with respect to the billiard table at the time of impact.
31	11.8.2	--- the expression $m_1v_1 + m_2v_2 = m_1v_3 + m_2v_4$ as the correct conservation statement to be applied to the billiard ball collision. (Ref 11.8.1).
32	11.8.3	--- the statement that total momentum of a system involved in an inelastic collision will remain the same after the collision as it was before.
33	11.8.4	--- the fact that the two bodies which make up the coupled mass after an inelastic collision will have the same velocity after impact.
34	11.8.5	--- the unknown quantity (i.e. the quantity to be determined in the problem initially stated in 11.8.3. (Equation has been simplified by now to read: $m_1v_1 = v_3(m_1 + m_2)$ from which the student is to select v_3 as the unknown.)

35	11.8.6	--- the fact that the velocity of the coupled mass (v_3) should be smaller than the velocity of the moving car was originally. (Ref 11.8.3).
36	11.8.7	Remedial
37	11.8.8	--- the correct numerical value for the velocity of the coupled mass after the inelastic collision (Ref 11.8.3).
38	11.8.9	--- given a problem in which a bullet of known mass is fired into a wood block of known mass moving toward the bullet at known speed, the block being brought to rest by the collision, to select the terms that drop out of the equation $m_1v_1 + m_2v_2 = m_1v_3 + m_2v_4$. (i.e., become zero).
39	11.8.10	--- the velocity of the wood block before collision as the proper negative quantity, the velocity of the bullet having been given a positive sign. (Ref 11.8.9)
40	11.8.11	--- the correct answer for the initial velocity of the bullet. (Ref 11.8.9).
	11.9	Upon completion, the student must be able to answer questions relative to a baseball thrown and dropped on the Moon.
AV 1	11.9.1	--- the fact that a baseball player on the Moon would need a mitt in catching a flat-trajectory throw from third base to first base.
AV 2	11.9.2	--- the statement that a ball dropped from the top of an Empire State building on the Moon would have less momentum at the bottom, but that a man who caught it would still require a mitt.
	11.10	Upon completion, the student must be able to answer questions dealing with the average force applied to a nail by a descending hammer, given the speed of the hammer, its mass, and the contact time with the nail.
AV 3	11.10.1	--- the correct value of the average force applied to the nail by the hammer, given the mass, speed, and contact time.
AV 4	11.10.2	--- the change in the average force due to a specified change in the mass of the hammer, all other factors remaining the same.
AV 5	11.10.3	--- the change in the average force due to a specified change in the contact time, all other factors remaining the same.

	11.11	Upon completion, the student must be able to answer questions relative to the situation where a ball of known mass strikes a wall of known resiliency, with a known bounce-back velocity.
AV 6	11.11.1	--- the impulse of the ball on the wall, considering the wall to be absolutely unyielding.
AV 7	11.11.2	--- the effect on the bounce-back velocity when the wall is considered to yield to a small degree.
	11.12	Upon completion, the student must be able to answer specific and relevant questions that stem from the brief film CONSERVATION OF MOMENTUM - ELASTIC COLLISIONS. (Ealing-Stull Series).
AV 8	11.12.1	--- the fact that, for a 1M driver colliding with a 1M target at rest, the momentum of the driver is completely transferred to the target.
AV 9	11.12.2	--- the fact that, for a 1M driver colliding with a 3M target at rest, the resulting momentum of the 3M target is greater than that of the 1M glider after impact.
AV 10	11.12.3	--- zero velocity as the velocity of the 3M glider after the second collision with the 1M glider. (That is, all the momentum of the 3M transferred).
	11.13	Upon completion, the student must show that he has understood the development presented in the brief film CONSERVATION OF MOMENTUM - INELASTIC COLLISIONS by calculating the percentage error in the second through the fifth runs displayed in the film.
AV 11	11.13.1	--- the proper range for the percentage error in the data obtained in experiment 1, trial 2 according to his own calculations. (Ref 11.13)
AV 12	11.13.2	--- the proper range for the percentage error in the data obtained in experiment 2, trial 1 according to his own calculations.
AV 13	11.13.3	--- the proper range for the percentage error in the data obtained in experiment 2, trial 2 according to his own calculations.
AV 14	11.13.4	--- the proper range for the percentage error in the data obtained in experiment 3 according to his own calculations.

LESSON 12

Work, Energy, and Power

	12.1	Upon completion, the student must be able to define work verbally and in the form of a simple equation, and must be able to use the concept of work and the proper MKS units in the solution of work problems.
1	12.1.1	--- the fact that, in terms of the fuel used in lifting material objects a given distance, the work done must be proportional to the force.
2	12.1.2	--- the statement that twice as much gasoline would be consumed by a gasoline engine which lifts a given weight x ft as would be consumed by the same engine lifting the same weight ½x ft, all other things equal.
3	12.1.3	--- the statement that the work done by a force is directly proportional to the distance through which the force moves.
4	12.1.4	--- the correct MKS unit for work (newton-meter) after the proportionalities have been combined to give $W = kFd$ and after we have arbitrarily assigned a value of unity to a dimensionless "k."
5	12.1.5	--- a unit that is not suitable for work expression. (nt/m as against the nt-m and the joule).
6	12.1.6	--- the fact that a force exerted on a body at right angles to the direction in which the body moves (due to some other force) does no work on the body.
7	12.1.7	--- the product of force and displacement due to the component of the force in the direction of the displacement as the proper expression of the work done by a force whatever may be its angle to the line of motion.
8	12.1.8	--- the work done by a boy in climbing a given vertical ladder, the weight of the boy being known. (BE system. The assumption is made that the student will be able to select the ft-lb as the only applicable work unit given in the problem based upon what has gone before.)
9	12.1.9	--- the work done in moving a safe of given weight (nt) by a given force (nt) over a given horizontal distance (m).
	12.2	Upon completion, the student must be able to define kinetic energy as the energy of a mass in motion, derive the expression $KE = \frac{1}{2}mv^2$ from work-energy conservation considerations, and define the proper MKS

unit for kinetic energy.

10 12.2.1 --- the product ma as a suitable replacement for F when we want to express the force that has acted on a mass m to give it an acceleration a.

11 12.2.2 --- the expression $v^2 = 2ad$ as the correct one to be used for expressing the final velocity of a body in terms of its acceleration and displacement.

12 12.2.3 --- the statement that neither of the two answers given is correct, for the following question: if we substitute (in W = Fd) ma for F, and $v^2/2d$ for a, to which of the following does the expression simplify?

$$W = \frac{mv^2}{2d} \qquad \text{or} \qquad W = mv^2$$

13 12.2.4 --- a suitable unit for kinetic energy in the MKS system

12.3 Upon completion, the student must be able to solve verbal and numerical problems involving the kinetic energy of moving masses.

14 12.3.1 --- the correct kinetic energy of a moving block whose mass is given in grams and whose speed is given in cm/sec.

15 12.3.2 --- the distance over which a given constant force must act in order to impart a given speed (m/sec) to a cart of given mass (kg). (Ideal conditions).

16 12.3.3 --- the correct work done in lifting a block of given mass (kg) vertically over a given distance (m).

12.4 Upon completion, the student must be able to define potential energy (PE), recognize that under ideal conditions the PE of a body raised to a height is equal to the work done in raising it vertically to that distance, or PE = wh, and recognize that the MKS unit of PE is the joule.

17 12.4.1 --- the fact that when the block of the previous MBO (12.3.3) has been lifted to the raised platform and rests there, its kinetic energy is zero.

18 12.4.2 --- the quantity velocity as the one which must be determined in order to calculate the KE of the block (ref 12.4.1) when allowed to fall freely from the platform to the ground.

19 12.4.3 --- Remedial.

20 12.4.4 --- the statement that we are justified in saying that the work done on the block stored energy in it, the

magnitude of the stored energy being equal to the work done initially on the block against gravity.

12.5 Upon completion, the student must be able to relate the potential energy stored in a spring, an explosive, etc., to the work done in storing this energy, or the kinetic energy this PE can become under ideal conditions.

12 12.5.1 --- the potential energy the explosive powder a bullet cartridge must have had calculated from the given values of the mass of the bullet (grams) and the muzzle velocity of the bullet (m/sec) using conservation of energy considerations.

22 12.5.2 --- the height from which a stone must have been dropped (given mass in kg) if the impact speed as it reaches the ground after free fall is given in (m/sec).

12.6 Upon completion, the student must be able to solve a multistep problem in which the mass of an object (kg) is given, and the height from which it is dropped is also given, to find the time required for it to reach the ground, and its PE and KE at various intermediate times.

23 12.6.1 --- the correct equation that will permit him to find the time of fall directly from the data given (ref 12.6) (Time turns out to be 3.00 sec)

24 12.6.2 --- the correct values of both PE and KE of the fallen ball after a time of 3.00 sec.

25 12.6.3 --- the fact that the speed of the falling object (ref 12.6) must be found at the end of t = 1.00 sec if we want to determine the KE of the ball at this time using $KE = \frac{1}{2}mv^2$.

26 12.6.4 --- the kinetic energy of the ball (ref 12.6) after the speed of the ball for t = 1.00 sec has been calculated using v = gt.

27 12.6.5 --- the statement that the total energy of the system involving the ball and the earth is, at any time, the sum of the instantaneous values of the PE and KE of the system.

28 ----- Notebook check.

12.7 Upon completion, the student must be able to analyze the motion of a simple pendulum in terms of the distribution of KE and PE in various parts of its swing.

29	12.7.1	--- the statement that the PE of a pendulum bob that has been displaced so that it has risen a vertical distance h is mgh.
30	12.7.2	--- the fact that, when the released bob passes through the lowest point of the arc, its total energy comprises KE (zero reference level taken as the lowest point in the arc).
31	12.7.3	--- the fact that the magnitude of the PE at the highest point of the swing (on the opposite side of the starting position) is identical with the PE initially, assuming ideal conditions.
	12.8	Upon completion, the student must be able to solve a problem in which he is to determine the kinetic energy of a bomb dropped from a plane after it has fallen a specified distance toward the ground, given the initial altitude of the plane and the mass of the bomb (MKS units).
32	12.8.1	--- (Review) the correct equation for KE given mass and velocity.
		(Note: 12.8 is accomplished here by means of a short linear program involving the problem in 12.8 and one additional one of the same variety.)
	12.9	Upon completion, the student must be able to define mechanical power, recognize its units, and use them in calculations of simple power problems.
33	12.9.1	--- time as the factor which appears in certain problems where it is to be determined how fast a given amount of work can be done.
34	12.9.2	--- the power consumed by a man, given the weight of the man, the height of a vertical ladder he climbs, and the time required for the climb (MKS units only).
35	12.9.3	--- the statement that the watt, defined as a joule per second, as a unit of power.
	12.10	Upon completion, the student must be able to solve power problems of second order difficulty.
36	12.10.1	--- the work done per minute by an electric motor whose power is given in watts.
37	12.10.2	--- the fact that the watt-second is a unit of work or energy, equivalent to a joule.

38	12.10.3	--- the fact that a kilowatt-hour is a unit of work or energy.
39	12.10.4	--- the fact that, in the modified power equation $P = F\Delta d/\Delta t$, the factor $\Delta d/\Delta t$ may be replaced by v, or speed of the body on which F acts.
40	12.10.5	--- the statement that power is a scalar quantity.
41	12.10.6	--- (Review and contrast) the fact that for two balls each of 0.20 kg mass moving respectively as a system, one with a velocity of +v and the other with a velocity of -v along the same line, the total momentum of this system is zero.
AV 1	12.1.4	See page 12-54 of the MBO LIST.
AV 2	12.1.7	See page 12-54 of the MBO LIST.
AV 3	12.1.10	--- the statement that the constant k in $W = kFd$ is dimensionless and set equal to unity because we define our work unit in terms of unit force and unit distance.
	12.11	Upon completion, the student must be able to find the work done in a horizontal direction by a force at some angle greater than zero degrees to the horizontal by trigonometry applied to the resolution problem.
AV 4	12.11.1	--- the correct answer to a problem in which the angle made by F to the horizontal is given, and in which the force is given as well as the horizontal displacement, to find the work done by F.
AV 5	12.11.2	--- the fact that all the work in the problem described is being done against friction if the velocity of the block is constant in the horizontal direction (Ref 12.11)
AV 6	12.11.3	--- the magnitude of the vertical component of F in the problem described (ref 12.11)
	12.12	Upon completion, the student must recognize that work must be done in stopping a moving mass, i.e., bringing it to rest from some finite velocity.
AV 7	12.12.1	--- the fact that any force (given sufficient time) acting on a body in a direction opposite that of its motion will ultimately bring it to rest.
AV 8	12.12.2	--- the statement that when a moving body is brought to rest by the force exerted on it by a hand pushing in a direction opposite that of its motion, the body does work on the hand.

AV 9	12.12.3	--- the statement that, if the moving body does work on the hand, then the hand must do an equal amount of work on the body in the opposite direction.
	12.13	Upon completion, the student must recognize that under ideal conditions the PE stored in a body in a gravitational field is the same regardless of the path taken to raise it to a given height.
AV 10	12.13.1	--- the fact that the work required to move an object horizontally on a frictionless surface zero.
AV 11	12.13.2	--- the statement that PE acquired by a body raised to a given height is independent of the path taken to bring it to this height.
	12.14	Upon completion, the student must be able to calculate the percentage errors of the experimental values obtained for the data given in the brief film CONSERVATION OF ENERGY (Ealing-Stull Series).
AV 12	12.14.1	--- select the correct range in which the % error for part I of the film appears.
AV 13	12.14.2	--- select the correct range in which the % error for part II of the film appears.
AV 14	12.14.3	--- select the correct range in which the % error for part III of the film appears.

LESSON 13

Internal Energy, Heat, and Temperature

	13.1	Upon completion, the student must be able to relate qualitatively work done against friction to the accompanying increase of temperature.
1	13.1.1	--- the fact that, for a real body resting on a real surface, an increase in weight of the body results in an increase in friction.
2	13.1.2	--- the statement that the force of friction acting to retard a body moving with uniform velocity on a real surface must be equal and opposite to the force required to produce the uniform velocity.
3	13.1.3	--- the correct value of the force of friction, given the work done on a body when it is moved horizontally at uniform speed over a given distance.

4	13.1.4	--- the statement that neither the PE nor the KE of a body changes when the work done on the body is used solely to overcome friction.
5	13.1.5	--- the fact that one must look for some other form of energy into which the work done against friction is converted other than a change of PE or KE.
6	13.1.6	--- the statement that a block dragged horizontally over a plank for a long distance will probably feel warmer at the end of the trip than it did before.
	13.2	Upon completion, the student must be able to relate an increased temperature to the increase of internal kinetic energy of the body undergoing the temperature increase.
7	13.2.1	--- the fact that adding heat to a fluid causes its molecules to move with a greater average speed.
8	13.2.2	--- the fact that an average increase in molecular speed as a result of heat added is tantamount to saying that there will be an increase in the average kinetic energy of the molecules.
	13.3	Upon completion, the student must be able to define the fixed points on the Fahrenheit and Centigrade Temperature Scales, convert freely from one to the other, and solve various problems relating to thermometers.
9	13.3.1	--- <u>temperature</u> as the quantity measured by a thermometer
10	13.3.2	--- the Fahrenheit thermometer as the one used in the United States for ordinary temperature measurements.
11	13.3.3	--- the correct number of Fahrenheit degrees between the boiling and freezing points of water on that scale.
12	13.3.4	--- the fact that the Fahrenheit degree is 5/9 the size of the Centigrade degree.
13	13.3.5	--- the fact that, when $y^\circ C = x^\circ F - 32^\circ F$ as an equation is divided by $5^\circ C = 9^\circ F$, the result is reducible to $$y = \frac{5(x - 32)}{9}$$
14	13.3.6	--- $140^\circ F$ as the equivalent of $60^\circ C$.
15	13.3.7	--- $5^\circ F$ as the equivalent of $-15^\circ C$.

16	13.3.8	--- -40° as the temperature at which the F and C thermometers would read the same.
17	13.3.9	--- 18.0° as the rise shown by a Fahrenheit thermometer for an equivalent rise of 10.0° on a Centigrade thermometer.
18	13.3.10	--- 75.0 C° as the rise of temperature of a Centigrade thermometer which is in the same bath as a Fahrenheit thermometer which has gone from 68.0° F to 203° F.
19	-------	Notebook Check.
	13.4	Upon completion, the student must be able to differentiate between <u>heat</u> (flow of energy from one body at a higher temperature to another at a lower temperature) and <u>internal energy</u> (total molecular energy in a body).
20	13.4.1	--- the fact that there will be a flow of heat through a conducting medium joining two bodies at different temperatures, the flow occuring from the one of higher to the one of lower temperature.
21	13.4.2	--- the fact that heat energy will not move from one body to another if the temperatures of the bodies are the same.
	13.5	Upon completion, the student must be able to apply the principle of conservation of energy to situations involving the compression of gases.
22	13.5.1	--- the statement that heating a gas by compression does <u>not</u> involve a flow of heat from a hot to a cold body.
23	13.5.2	--- the correct expression for energy conservation in a situation where work is done on the gas as work done = ΔKE + ΔPE + internal energy.
	13.6	Upon completion, the student must be able to justify the statement that, for a given mass of a given substance, the mass has the greatest amount of internal energy in its gaseous or vapor state, and the least in its solid state, with liquid between.
24	13.6.1	--- the statement that the influx of heat into ice causing the ice to melt to water at the same temperature does not change the kinetic energy of the molecules.
25	13.6.2	--- the fact that water at a given temperature, having a given mass contains more total internal energy in its liquid than in its solid state.

26	13.6.3	--- the fact that a given mass of water vapor or steam has a greater total internal energy content than the same mass of liquid water.
	13.7	--- Upon completion, the student must be able to answer questions and solve problems relating to internal energy of water as given by the relation $H = m\Delta t$.
27	13.7.1	--- the expression $H = m\Delta t$ as the correct equation for relating the change in internal energy to the mass and change of temperature of the water.
28	13.7.2	--- the correct answer to a problem in which he is to find the number of calories which must be added to a given mass of water to raise the temperature a stated amount.
	13.8	Upon completion, the student must be able to answer questions and solve problems in heat exchange involving changing state (vapor, solid, liquid) as well as changes of temperature within the state, for water.
29	13.8.1	--- the correct number of calories involved in changing 1 g of ice at 0° C to 1 g of water vapor at 100° C.
30	13.8.2	--- by analyzing the change of state graph of the prevous MBO, the statement which shows that the water is in its liquid state along with entire length of the curve from the ice "plateau" to the steam "plateau."
31	13.8.3	--- by analyzing the same graph (ref 13.8.1), the statement that the two plateaus would no longer be horizontal if water changed its temperature while it was changing state.
	13.9	Upon completion, the student must be able to analyze a temperature-heat graph for a hypothetical substance having characteristics different from water.
32	13.9.1	--- by analyzing the graph for a hypothetical substance, the number of calories required to raise the temperature of this substance (1 gram) over 1 C°.
33	13.9.2	--- by analyzing the graph for a hypothetical substance, the correct value of the heat of fusion and the heat of vaporization of this substance.
34	13.9.3	--- by analyzing the graph for a hypothetical substance, the correct answer for a problem in which he is to calculate the number of calories which must be removed from a given mass of the substance in its vapor state

		at a given temperature to convert it to a solid at its freezing point.
	13.10	Upon completion, the student must be able to answer a number of review questions dealing with momentum conservation in the inelastic collision between two putty balls.
AV 1	13.10.1	--- the correct momentum value for a 10 kg putty ball moving to the left with a given velocity (standard sign convention).
AV 2	13.10.2	--- the correct answer to a question which asks for the sign of the resultant momentum after two putty balls of different mass moving with the same speed in opposite directions collide.
AV 3	13.10.3	--- the correct answer to a question which asks for the sign of the resultant momentum after a collision of two putty balls of equal mass initially moving with the same speed in opposite directions collide inelastically.
AV 4	13.10.4	--- the correct response to the question, "Does the collision of two equal-mass, equal-speed oppositely directed putty balls represent a violation of the Principle of Conservation of Momentum?"
	13.11	Upon completion, the student must be able to answer questions relating to the glass-bead, heated-mercury demonstration used for illustrating a model of the kinetic molecular theory.
AV 5	13.11.1	--- the correct answer to the question as to why hollow glass beads on water in the same equipment as the mercury experiment would not work as well.
AV 6	13.11.2	--- the correct reason for the occasional bead which while on its way down, suddenly starts upward again.
	13.12	Upon completion, the student must be able to perform temperature conversions from Centigrade to Fahrenheit.
AV 7	13.12.1	--- the correct value for the standard room temperature on the Fahrenheit scale.
AV 8	13.12.1	--- the closest approximation to absolute zero on the Fahrenheit scale.
	13.13	Upon completion, the student must be able to recognize the pressure and temperature conditions which obtain in a system where a gas is expanding from one chamber into another through an orifice.

AV 9	13.13.1	--- the statement that the gas pressure in the chamber from which the gas comes is greater initially than the pressure in the chamber into which expansion occurs.
AV 10	13.13.2	--- the correct range of the temperature of the gas in the expansion chamber, given the temperature of the gas in the original chamber.
	13.14	Upon completion, the student must be able to relate the BTU to the calorie in simple problems.
AV 11	13.14.1	--- the correct equivalent of 1 BTU in calories.
AV 12	13.14.2	--- the solution to a simple problem involving an understanding of the BTU and the use of the equation $Q = mc\Delta t$.
	13.15	Upon completion, the student must be able to analyze a table of specific heats of common substances, indicating thereby an understanding of the meaning and use of specific heats.
AV 13	13.15.1	--- the solid metal which requires the least amount of heat for a given rise of temperature. (This and following questions refer to the Table in Data Item B of the Worksheet for Tape Segment 6).
AV 14	13.15.2	--- the best coolant.
AV 15	13.15.3	--- the second from the best coolant.
AV 16	13.15.4	--- the correct answer to a problem in which a given amount of heat is added to a sample of mercury to raise its temperature 1 C^{o}, to find the temperature rise to be expected if the same amount of heat were added to a sample of silver of the same mass.

LESSON 14

Gases, the Gas Laws, and Absolute Temperature

	14.1	Upon completion, the student must be able to answer questions relating to the pressure exerted by a gas and solve simple problems involving gas pressure.
1	14.1.1	--- the fact that, if the number of gas molecules colliding with each unit area on each of four walls of a container is not equal for a given period, the container might move about.

2	14.1.2	--- the statement that the system described in the Study Guide, page 66, Figure 3 for this lesson would be in equilibrium.
3	14.1.3	--- the expression P = F/A as the correct defining equation for pressure. (P = pressure, F = force, and A = area on which the force acts.)
4	14.1.4	--- the correct answer to a problem in which the pressure of the atmosphere must be added to the mechanical pressure of a weight on a piston in order to determine the gas pressure required to hold the weight on a piston
5	14.1.5	--- the fact that the pressure of a gas would appear to double if the volume were reduced to half if its initial value because there would be twice as many molecular-to-wall collisions for this condition.
	14.2	Upon completion, the student must exhibit understanding of a descriptive derivation of Boyle's Law, and be able to solve problems dealing with this law.
6	14.2.1	--- the fa[illegible] that it is necessary to know the weight of the pis[illegible]n-rod-table assembly in Figure 5, page 111 of this l[illegible]n before we can perform an experiment in which the change of volume of a gas is observed as the weights added to the table are increased.
7	14.2.2	--- the statement that the value for the total pressure shown in Figure 6, page 71 of this lesson was obtained by adding atmospheric pressure to the pressure caused by the added weights.
8	14.2.3	--- the fact that, since the steadily rising pressure causes a steadily decreasing volume, then volume cannot be directly proportional to the pressure.(ref Figure 6)
9	14.2.4	--- the fact that a constant product is the method to use to determine whether two variables are inversely proportional to one another.
10	14.2.5	--- the fact that the data given in Figure 6 seems to indicate that volume of a gas and pressure acting on it are inversely proportional to one another.
11	14.2.6	--- the statement that the temperature of a gas may affect the volume as well as the pressure does.
12	14.2.7	--- the correct answer to a problem in which the volume of a confined gas is given at a given pressure, to find the new volume when the pressure is changed to another stated value.

13	14.2.8	--- the correct answers to a 4-part problem in which the volume of a gas at normal atmospheric pressure is given, to find the pressure required to compress it to ¼ of its initial volume, the pressure to be stated in lb/ft^2, cm of Hg, nt/cm^2, and atmospheres.
	14.3	Upon completion, the student must develop a working understanding of absolute zero temperature and the manner in which the Kelvin temperature scale is used.
14	14.3.1	--- the fact that a given gas at two different temperatures holding up a piston in a cylinder may have the same pressure in both cases if the force exerted by the piston is the same in both cases, even though its volume may be different.
15	14.3.2	--- referring to some given data, the figure 3.66 cm^3 as the amount that a 1000-cm^3 sample of a confined gas will contract for each reduction of temperature of 1 C^o.
16	14.3.3	--- the fraction 1/273 as the correct value to answer the question: "What fractional part of 1000 cm^3 is 3.66 cm^3?"
17	14.3.4	--- the correct answer to a problem in which the new volume of 273 cm^3 of a gas is to be found when the gas is cooled from its initial temperature of 0^o C to -5.00^o C.
18	14.3.5	--- the correct answer to a problem in which a given volume of helium at a given temperature and pressure is cooled to -250^o C with no change of pressure, to find the new volume of the gas.
19	14.3.6	--- the equation: $^oK = {}^oC + 273^o$ as the correct expression to be used in converting a given centigrade temperature to the Kelvin scale.
20	14.3.7	--- one group of presumably equivalent temperatures on the centigrade and Kelvin scales which has an error.
	14.4	--- Upon completion, the student must be able to show the development of Charles' Law and solve problems involving this law.
21	14.4.1	--- the statement which shows that he can recognize that a given cooling curve has been transfered from a centigrade to a Kelvin axis. (Ref Figure 12, page 33 of study guide for this lesson).
22	14.4.2	--- the statement, based upon the study of the graph of

		of Figure 12, that the volume of a gas is directly proportional to its Kelvin temperature.
23	14.4.3	--- the correct new volume that a gas will occupy, given the initial volume, initial temperature and final temperature with no change of pressure.
	14.5	Upon completion, the student must be able to combine the expressions for Boyle's Law and Charles' Law to obtain the general form, and then solve problems involving the general form.
24	14.5.1	--- select $PV/T = P'V'/T'$ as the correct form from the combination of the expressions for Boyle's and Charles' laws.
25	14.5.2	--- the correct answer to a problem in which the volume of a gas at STP is given, to find its new volume at another temperature and pressure.
	14.6	Upon completion, the student must be able to define absolute zero as that temperature of a body at which none of the internal energy of this body can be transferred to any other body, regardless of the temperature of the second body.
26	14.6.1	--- the statement that the average speed of the atoms or molecules of a substance decreases when the substance is cooled.
27	14.6.2	--- the statement that a body at a temperature of absolute zero has very little internal energy.
28	14.6.3	--- the statement that, when two bodies at slightly different temperatures are brought into contact, heat will flow from the warmer to the cooler body until their temperatures are equalized.
29	14.6.4	--- the fact that heat cannot flow out of a body at absolute zero into any other body that it touches regardless of the temperature of the second body.
	14.7	Upon completion, the student must be able to analyze the assumptions made about ideal gases in formulating the kinetic theory.
AV 1	14.7.1	--- the fact that the random motion of the molecules in an ideal gas is due to the large number of intramolecular collisions that take place in a short time interval.
AV 2	14.7.2	--- the statement that molecules should be considered

as "points" in deriving the kinetic theory because they are so small compared to the distances between them.

AV 3	14.7.3	--- the fact that gravitational attraction between molecules in an ideal gas is assumed absent.
AV 4	14.7.4	--- the fact that, at any given instant, the number of collisions between the molecules of an ideal gas and any one wall of the container (assuming a perfectly cubical container) is the same for any other wall.
	14.8	Upon completion, the student must be able to solve simple problems involving conversions from one pressure unit to another, specifically for MKS units, bars, and millibars.
AV 5	14.8.1	--- the correct percent error made when 10 nt/cm^2 is used as normal atmospheric pressure. (Standard pressure)
AV 6	14.8.2	--- the number of nt/m^2 in 1 bar.
	14.9	Upon completion, the student must be able to solve simple problems involving the relation $P/T = P'/T'$ for constant volume conditions.
AV 7	14.9.1	--- the statement that the volume of air in a modern automobile tire remains essentially constant whether it is inflated or not.
AV 8	14.9.2	--- the correct new pressure of the air in an automobile tire, given the initial pressure and temperature and the final temperature.
AV 9	14.7.5	--- the fact that the assumptions made in deriving the kinetic theory of gases apply only to ideal gases.
AV 10	14.7.6	--- the fact that, for a given compression of a given initial volume of <u>real</u> gas, the rise of temperature due to the work done during compression would be less than it would be fore an ideal gas under identical conditions.